SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Swiss Research on Activated Sludge—Wuhrmann

Oil Field Waste Disposal—Pomeroy

Wood Pulp Industry Wastes Problem—Murdock

Equitable Stream Usage—Hess

JANUARY, 1954—VOL. 26, No. 1

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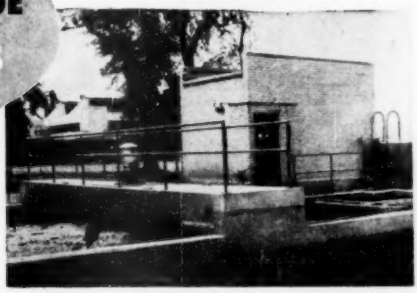

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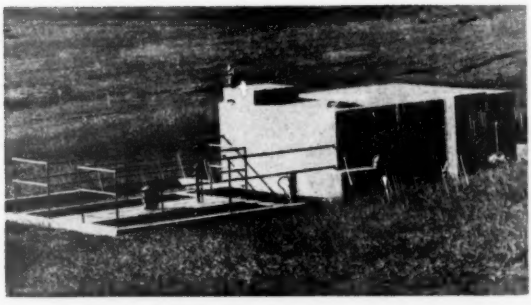

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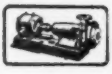

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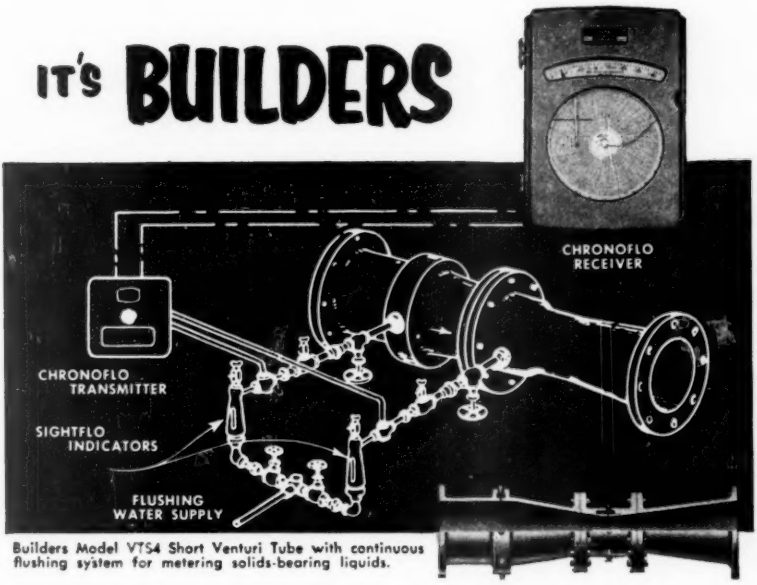

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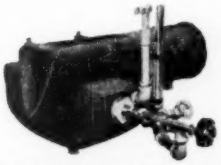

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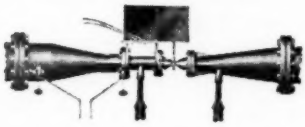

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October 11–14, 1954

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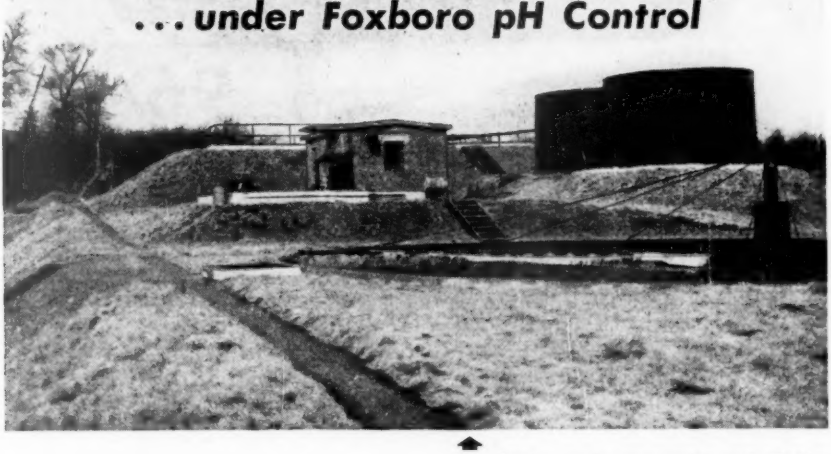
Two "Problem" Wastes Become a Neutral Effluent

...under Foxboro pH Control



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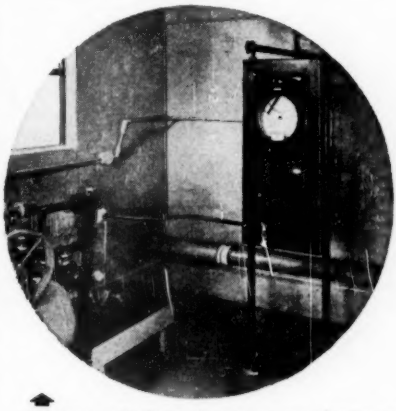

Foxboro pH Controller in pump house at Mansfield Bleachery regulates flows into the mixing basin.

FOXBORO pH CONTROLLERS

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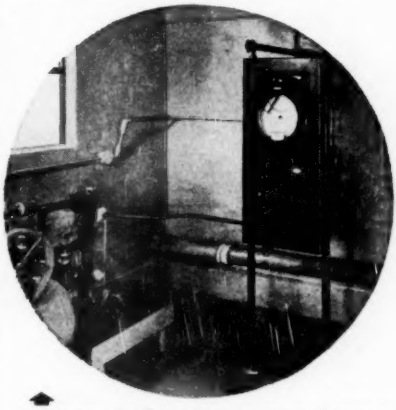

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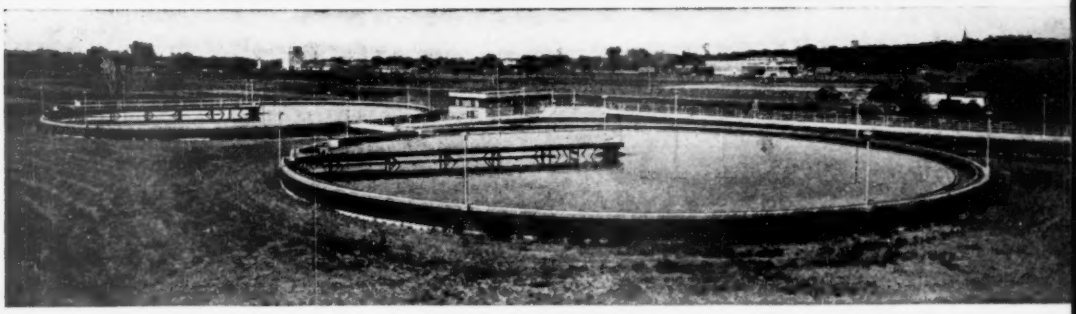

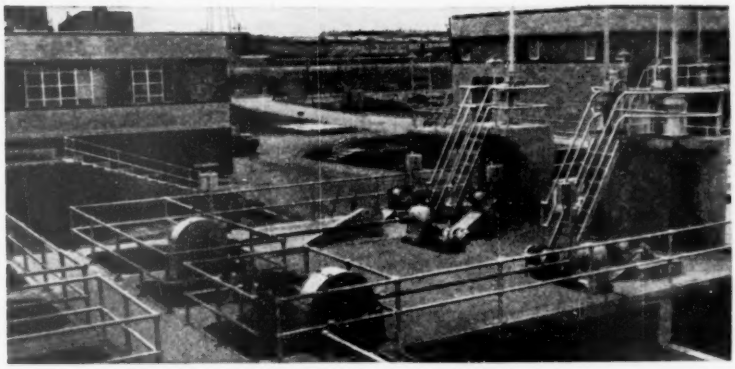

Link-Belt Circuline sludge collectors, mechanically-cleaned bar screens and Straightline grit collector help provide 114 mgd peak load capacity at Denver sewage treatment plant. Black & Veatch, Consulting Engineers.

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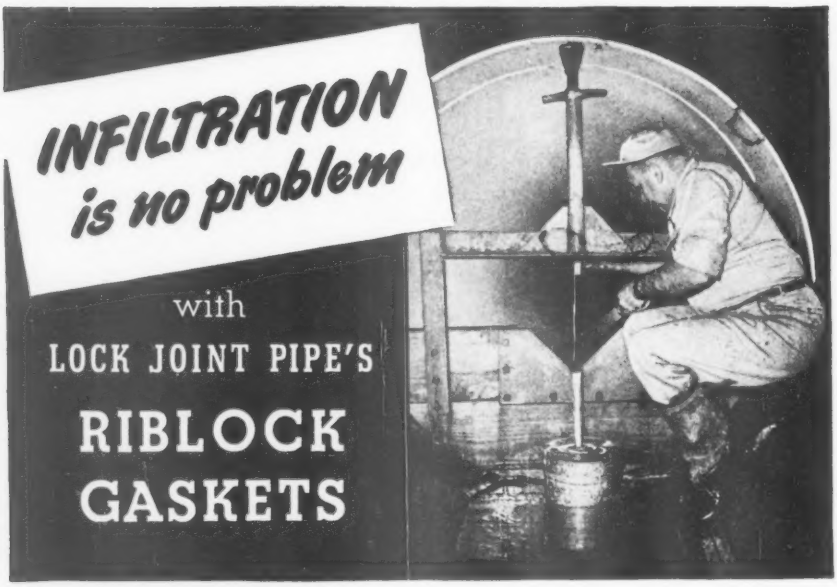

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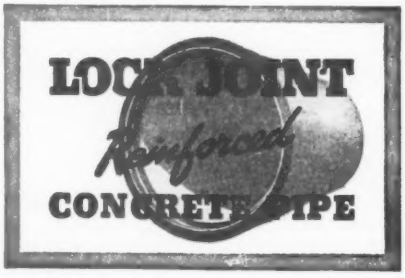

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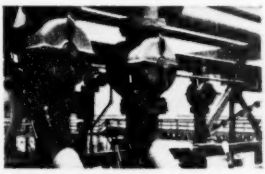

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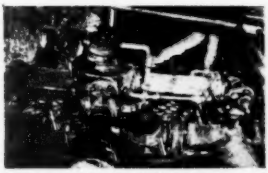

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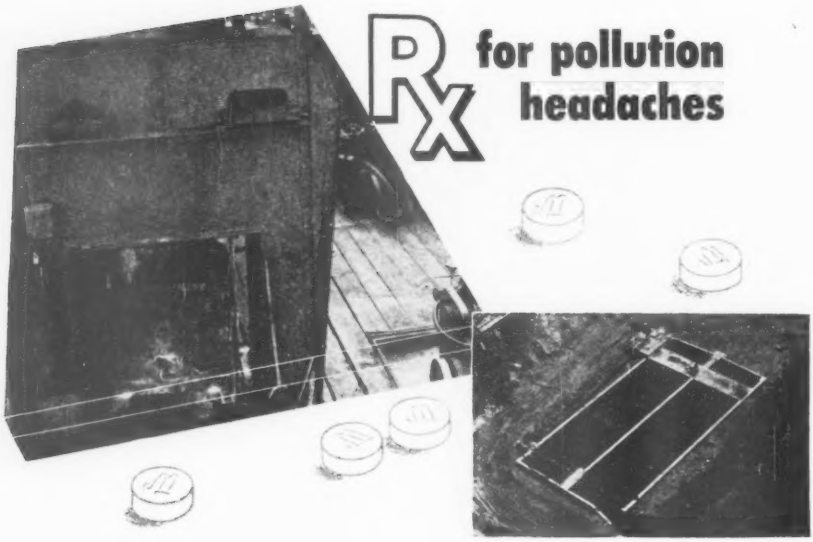

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FLOCCULATION: Jeffrey FLOCTROLS coagulate particles and promote rapid settling.

SETTLING: Jeffrey automatic, continuous Sludge Collectors scrape deposit to sump at end where it is pumped out and de-watered or sent to lagoons.

Hundreds of industrial wastes treatment plants throughout the nation are now Jeffrey-equipped. Scores of industries have found Jeffrey's wide engineering experience and broad line of proved equipment the best answer to pollution problems.

Write for descriptive literature.

Top photo: Jeffrey Standard V-Bucket type Grit Collector removing grinding sludge from settling pits where used grinding solutions have been collected at Pratt & Whitney Aircraft plant, East Hartford, Conn.

Above: Jeffrey-equipped API Separator removing oil at same plant.

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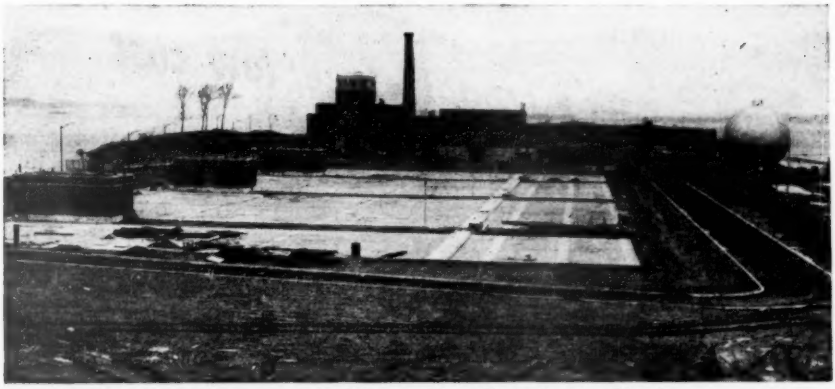
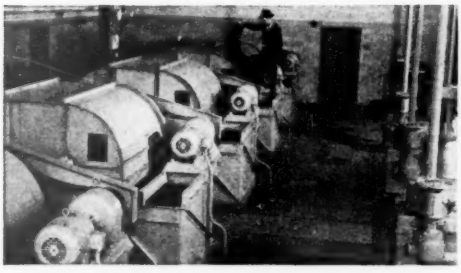


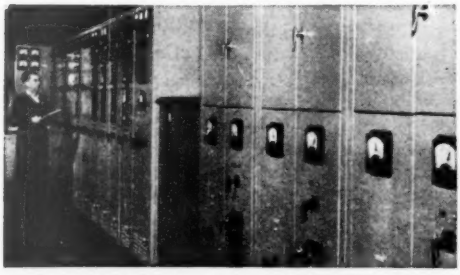
COMPLETELY SELF-SUFFICIENT when in full operation, Boston's Nut Island sewage treatment plant uses G-E 1-hp totally enclosed motors to drive sludge and grease pumps and sludge collectors.

New treatment plant brings clean waters to Boston

G.E. equipped Nut Island plant is first half of plan to make harbor recreation areas safe



SYSTEM BEGINS in grit room where raw sewage flow is controlled by gates (at right) and grid collectors (at left), both powered by G-E Tri-Clad* motors.



2400-VOLT POWER is distributed from this General Electric switchgear and limitamp control to four main pumps which constitute the heart of the flow system.

When Boston's new Nut Island sewage treatment plant at Quincy goes into full-scale operation in 1954, it will have a maximum capacity of 300-mgd and will be the first half of a long-range plan to make Boston Harbor waters safer for bathing and recreation.

The Construction Division of the Metropolitan District Commission of Boston, designers of the plant, were aided in extensive pre-construction planning by G-E application engineers, who helped design the entire electrical system, supervise installation, and specify standard equipment tailored to this plant's particular requirements.

Specialists in sewage-plant electrification, G-E application engineers are ready to work with *your* engineers or consultants, too. Backed by unexcelled engineering facilities, they'll help in designing a co-ordinated electrical system for your new plant or modernization project. Contact your local G-E Apparatus Sales Office early in the planning stage, or write Section 666-83, General Electric Company, Schenectady 5, New York.

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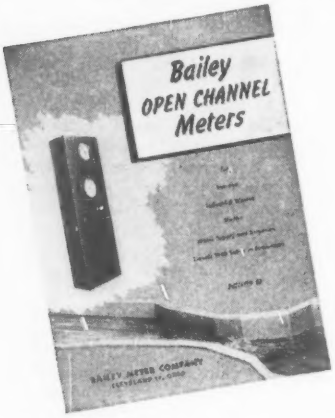

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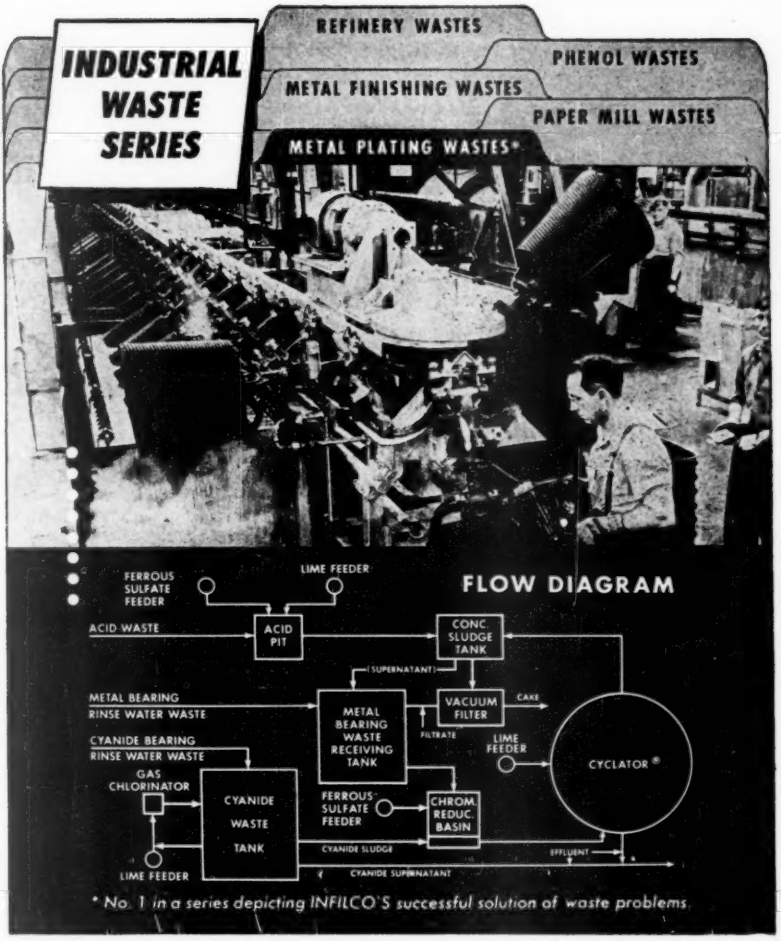

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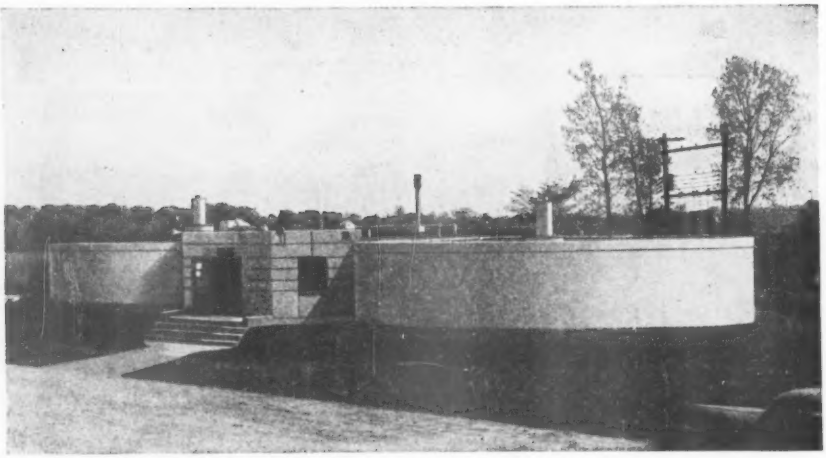

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 26 **January, 1954** **Number 1**

Contents

Sewage Works

High-Rate Activated Sludge Treatment and Its Relation to Stream Sanitation. I. Pilot-Plant Studies. By K. Wuhrmann 1

Research on Activated Sludge. III. Distribution of Oxygen in Activated Sludge Floc. By A. Pasveer 28

Reduction of Excess Sewage Flows at Milwaukee. By Raymond D. Leary 34

Sewer Pipe Roughness Coefficients. By Kenneth W. Cosens 42

Industrial Wastes

Trickling Filter Studies on Fine Chemical Plant Wastes. By F. E. Reimers, U. S. Rinaca and L. E. Poese 51

Disposal of Waste Water from Oil Fields in the Coastal Counties of California. By Richard Pomeroy 59

Water and Waste in the Wood Pulp Industry. By Harold R. Murdock 71

Discussion. By H. W. Gehm 80

Stream Pollution

The Equitable Use of Streams. By Seth G. Hess 83

The Operator's Corner

Metallizing Experience at Two Iowa Plants:

I. Marshalltown, Iowa. By L. F. Skorczeski 89

II. Fort Dodge, Iowa. By D. D. Douglas 91

Disposal of Wet Digested Sludge at Marshall, Missouri. By Henry Hayob 93

Maintenance and Operation of Primary Treatment Units. By Frank H. Miller ... 96

Interesting Extracts from Operation Reports: DeKalb, Ill.; Jackson, Mich. 103

Some Notes on Contemporary German Plants. By Gordon E. Mau 108

Tips and Quips 111

Federation Affairs

Twenty-Sixth Annual Meeting Report 113

Reviews and Abstracts 118

Proceedings of Member Associations

Alabama Water and Sewage Association 22a

Georgia Water and Sewage Association 22a

South Dakota Water and Sewage Works Conference 24a

Missouri Water and Sewerage Conference 26a

Rocky Mountain Sewage Works Association 28a

Equipment and Supply Lines 30a

W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois

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Sewage Works

HIGH-RATE ACTIVATED SLUDGE TREATMENT AND ITS RELATION TO STREAM SANITATION

I. Pilot-Plant Studies

By K. Wuhrmann

Federal Institute of Water Supply, Sewage Purification, and Water Pollution Control, Swiss Federal Institute of Technology, Zurich, Switzerland

Rather favorable dilution conditions for sewer discharges into the streams and lakes of most Swiss communities promoted the concept that a "partial" treatment of sewage might be the most economic way to achieve an extensive stream sanitation program. Experiments on a technical scale were started in 1937 with the aim of studying the operational requirements of the activated sludge process at high load ranges. After repeated interruption during the war, the studies were intensified and completed in the past six years. The experiments, which may be of general interest, have been published in detail elsewhere (1).

The problem of the high-rate activated sludge process has also been discussed in the United States for many years (2)(3)(4)(5)(6)(7)(8)(9). It seemed worthwhile, therefore, to summarize the observations in This Journal, in so far as they might be of some value for the American reader. The present article contains the conclusions of all 29 experiments which have been evaluated. However, only the operational and analytical data of a few runs have been assembled in detail in Table VI, partly as examples for the experimental technique and control, and partly because these values are needed for the discussion. The load range studied in the 29 pilot-plant experiments is indicated in Figure 1, which for the sake of comparison also contains data from plants in actual operation in the United States (10) and data of experimental runs at the Jamaica plant of New York City (4)(5)(6).

The experimental work with high-rate treatment of sewage was extended to the control of the effect of the plant effluents in rivers. Observations of the behavior of the biocoenosis in artificial brooks, fed with clean river water or mixtures of river water with plant effluents, constitute an important part of the critical examination of the quality of sewage purification performed in the pilot-plant experiments. The technique of model tests and the conclusions to be drawn in connection with high-rate sewage purification are contained in a later paper of this series.

The Pilot Plant

A pilot plant of the characteristic Kessener construction served for all the experiments described in this paper. Details of the plant layout have been given by Kropf (11). The plant consisted of two sections of identical construction, thus permitting experiments in duplicate under identical conditions. Each plant consisted of an aeration basin (volume approximately 6,750 cu. ft.), which was divided by four walls into five compartments of 1,350 cu. ft. each. The compartments were used as

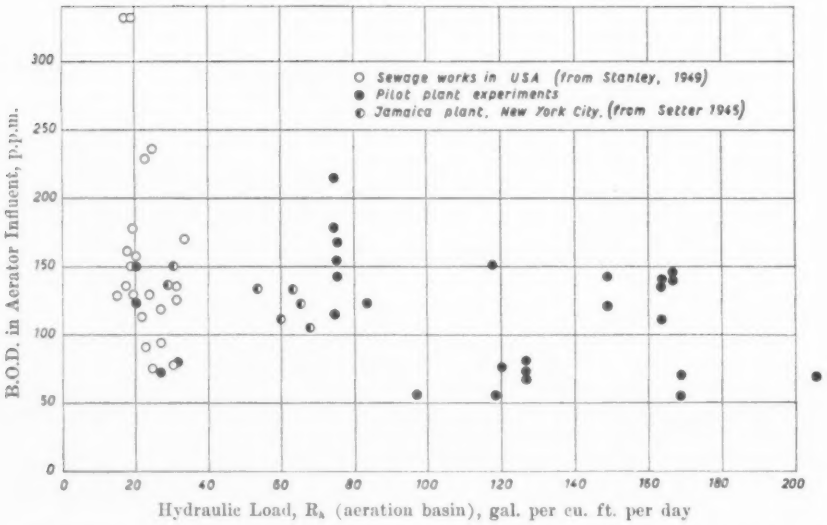

FIGURE 1.—Loading range of activated sludge pilot-plant experiments compared with operating plants in the United States and with experiments at the New York City Jamaica plant.

a whole or singly for the experiments according to the hydraulic load of the aerator to be studied. A final clarifier of the upflow type (pyramidal shape) with a total volume of 2,720 cu. ft. (flow-through-volume about 2,500 cu. ft.) was provided for each aeration chamber. Lifting of the return sludge was originally accomplished by lifting wheels. Later on a centrifugal pump

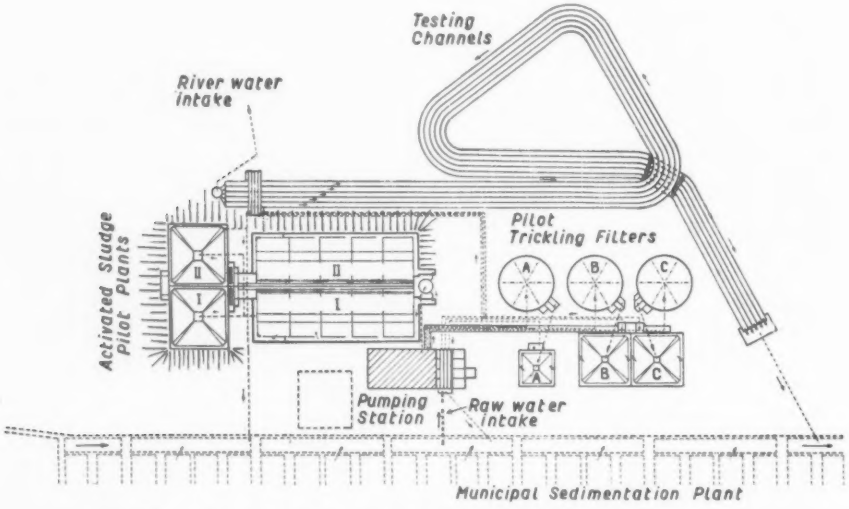

FIGURE 2.—Schematic layout of pilot plants at Zurich experimental station.

was used. It was necessary in most experiments to recirculate relatively large volumes of sludge to prevent clogging of the sludge pipes. In most of the later experiments return sludge was mixed with the sewage entering the aerator. Because of the limited volume of the secondary sedimentation tanks it was generally necessary to use only one or two compartments of the aeration basin in runs at hydraulic loads above 110 g.p.d. per cu. ft. Short circuits in the relatively small aeration compartments were then partly eliminated by subsurface introduction of the raw sewage and a special arrangement for the outlet. A general layout of the plant is given in Figures 2 and 3.

The raw sewage and the return sludge were dispensed and measured by Poncelet weirs. Excess sludge was drawn, in general, once a day from the return sludge conduit within a

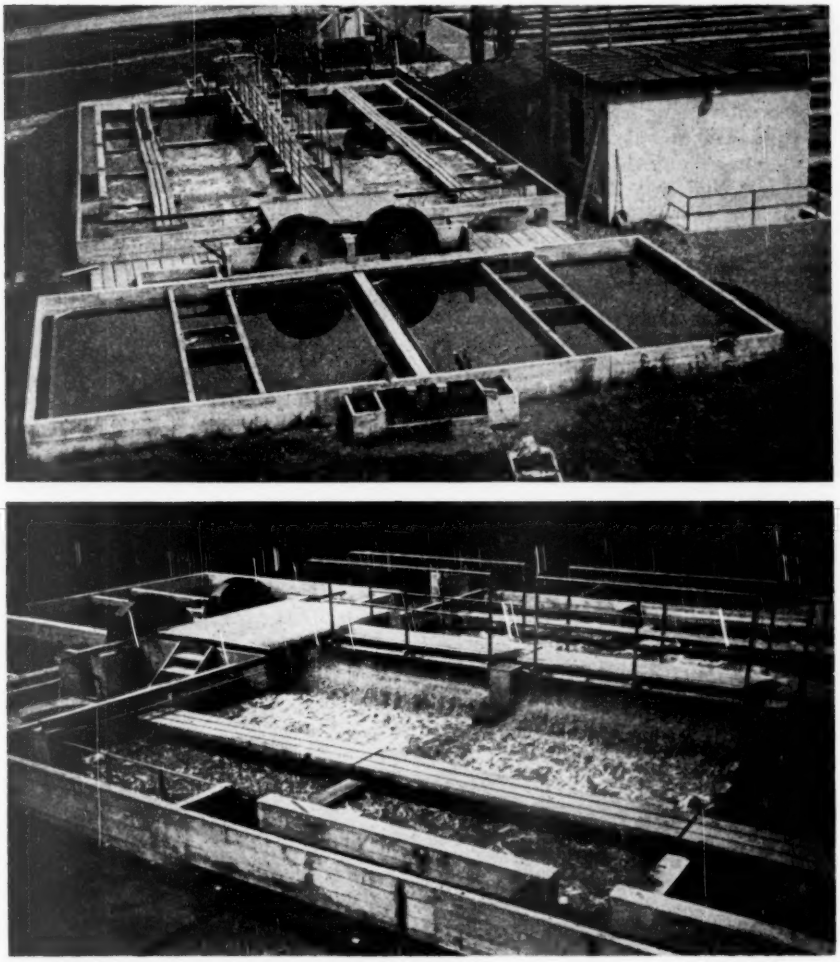

FIGURE 3.—Views of the duplicate activated sludge plants, showing clarifiers and brush aeration basins.

period of 1 or 2 hr., and was measured over a V-shaped weir.

Raw Sewage Characteristics

The pilot plant was situated within the municipal sewage treatment plant of the city of Zurich. This sewage works is equipped with grit chamber, mechanically-cleaned bar screen, and sedimentation basins (12). Settled sludge is digested in heated digestion tanks. The effluents of the sedimentation tanks (Travis system) are collected in diversion channels which lead to the River Limmat. As used herein "raw sewage" is always understood to be the effluent of the plain sedimentation plant of the city of Zurich. This effluent was pumped for the pilot plant from the southerly diversion channel of the city's plant (see Figure 2).

The sewage flow to the municipal works averages about 40 to 42 m.g.d. during dry-weather, exceeding 66 m.g.d. in wet weather. (Storm-water overflows at different points on the intercepting sewers handle the remainder.) The dry-weather flow corresponds to about 130 to 150 g.p.c.d. Part of this large quantity is due to a considerable amount of drainage water from the residential quarters of the town, mean water consumption being only about 100 g.p.c.d.

The total detention time in the city's works was measured several times by following a regular peak in the chloride concentration, arriving each morning with the approximate mean daily flow. Detention time from bar screen to intake of the pilot plant during dry weather was 40 to 45 min.

The composition and concentration of the primary effluent may be estimated from Figure 4, which gives a typical example of a 24-hr. diagram. The sewage is predominantly of domestic origin, although large quantities of industrial wastes are introduced into the sewers by some textile works, two breweries, the municipal slaughterhouse, and some minor industries. Comparison of the average B.O.D. concentrations with those of American cities indicates much the same conditions. The proportions of certain components of the settled sewage of Zurich in comparison with Chicago sewage are summarized in Table I. Considerable amounts of impurities in the settled sewage are carried by the suspended solids (Table II). This proportion of "fixed" impurities is of some interest for the evaluation of the purification capacity of a biological treatment process, because it is obvious that the elimination of suspended primary solids may simulate a high degree of treatment of the sewage, even

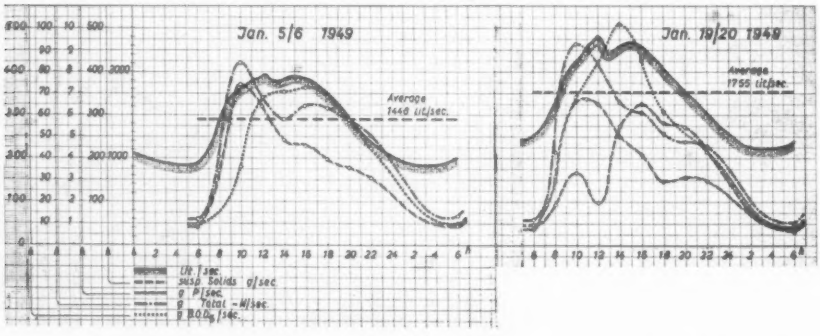

FIGURE 4.—Diurnal variation in dry-weather flow and characteristics of the Zurich primary treatment plant effluent.

TABLE I.—Proportions of Sewage Components in Settled Zurich Sewage (Pilot-Plant Influent) and in American Sewage Works

Proportion	Zurich		Chicago South-West 1946	Chicago North 1946	Jackson, Mich. 1946
	1949	1950			
B.O.D.: Total nitrogen	4.9:1 to 4.5:1	5.8:1	6.2:1	6:1	6.6:1
Organic carbon: Total N	2:1 to 1.7:1	3.3:1			
Nitrogen components in % of total Nitrogen:					
Organic N	28.3 to 29.1	42	59	49	40
NH_4-N	65 to 67	65	41	51	60
NO_2-N and NO_3-N	4 to 6	2.8	0	0	0

when no considerable oxidation of dissolved organic matter has taken place. Thus, in comparisons of the efficiency of different biological treatment processes, the concentration of suspended solids in the raw sewage must be taken into account (for example, comparison of the efficiency of these partial treatment experiments with those of *Setter* (5) in the New York City Jamaica plant, where large quantities of primary solids are carried by the raw sewage).

Technique of Studies

The problems to be studied in the pilot plant necessitated a rigorous uniformity of the basic operation conditions, such as flow of raw sewage and return sludge, concentration of suspended solids and oxygen in the mixed liquor, etc. Daily records of these data were kept and in general only small variations occurred. The rather uniform composition of the raw sewage helped greatly, of course, in maintaining a steady state of plant performance.

For the sake of simplicity of experimental technique and sampling methods, a simplified load distribution curve over the 24-hr. period was chosen, either by constant hydraulic load over 24 hr. or by using a two-step load. Of course, this simplification produced a considerable deformation of the natural load curves of the different sewage components, as may be seen by the graphic transformation of the natural flow distribution in the effluent of the city's sedimentation plant according to the inflow of the pilot plant under different experimental conditions (Figure 5). Constant feeding of the pilot plant equalizes the load within the 24 hr. period, whereas two-stage feeding results in high peak loads in the daytime. The 24-hr. sum of sewage components differed much less, however, in the three load conditions when based on the same daily total of sewage flow. It is believed, therefore, that the results of the experiments were not influenced to a significant degree by the special load conditions applied. They are regarded as directly transferable to practical cases.

The experimental period for each run (which is understood as the period of steady-state operation and plant per-

TABLE II.—Components of Sewage Fixed in Suspended Solids of Settled Zurich Sewage (Influent to Pilot Plant); Fall, 1950

Component	Settled Sewage (p.p.m.)	After Filtration[1] (p.p.m.)	Fixed in Susp. Sol. (%)
Suspended solids	120	0	—
Oxygen cons., by $KMnO_4$	314	133	57.6
Org. nitrogen, as N	8.82	4.72	46.5
Total phosphorus, as P	1.99	0.91	54.3
Organic carbon, as C	82.1	20.9	74.6

[1] Membrane filters.

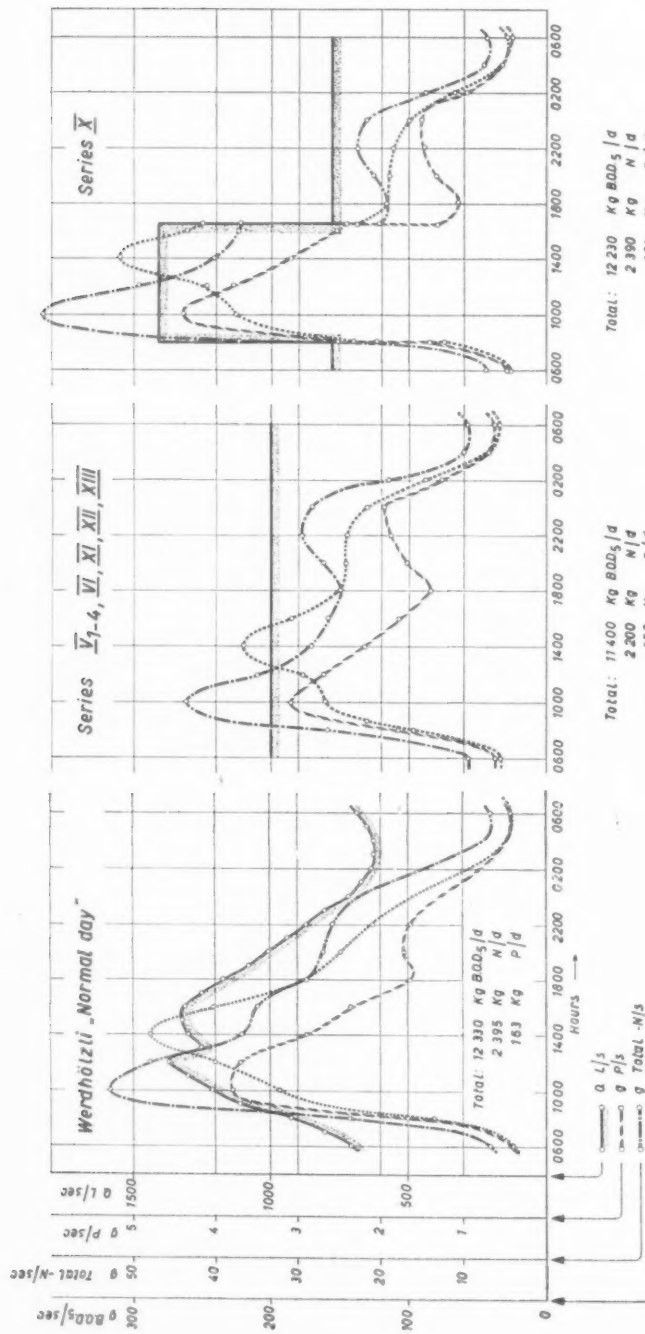

FIGURE 5.—Sewage flow curves for different experimental runs compared with the natural sewage flow in the Zurich municipal plant. Note the respective deformation of the flow curves of sewage components.

formance at experimental conditions) lasted, in general, several months. Within this period, a shorter term (6 to 8 weeks) was chosen for the detailed analytical investigations. There were, in general, two to three sampling days per week. The values of Table VI represent the means of the individual analyses of the sampling period (10 to 20 observations). The plant operating data given in Table VI are averaged over the period of analytical control only.

Replications of runs under as similar operating conditions as possible were carried out during these years. Thus, it was possible to investigate and compare certain sets of operating conditions during periods of different strength of raw sewage. Due to heavy food rationing during the war, the sewage was extremely weak in 1944 and 1945; thus, a considerable variability of sewage strengths has been covered by experiments otherwise more or less comparable.

From time to time, runs at high rates were compared in the parallel plant with runs under conventional conditions. Thus, a continuous relation between high- and low-rate treatment was guaranteed. This was important for establishing later on certain relations of plant performance and plant load, which were the aim of the experiments.

Sampling and Analytical Procedures

The analytical data supporting this article are exclusively based on 24-hr. samples collected by a simple automatic sampler. In runs with two load ranges in 24 hr., sampling was executed for each load period individually and the final sample was then composited in proportion to the loads. Sampling times at plant influents and effluents were graduated according to the mean detention period of the water between sampling points (estimated by following the regular chloride peak in the sewage through the plant).

Most analytical procedures were carried out as prescribed in "Standard Methods" (13) or in "Deutsche Einheitsverfahren." Exceptions to this included: Sludge respiration, by micromanometric methods at 25° C.; organic carbon, according to van Slyke and Folch (14); amino acids, according to van Slyke *et al.* (15); potassium (in sludge), by flame spectrophotometry.

Remarks on Pilot-Plant Operation

Maximum Purification Rates

The total time required for the breakdown of a given quantity of organic matter in sewage by activated sludge is a function of sludge concentration, other conditions being equal. On the other hand, there is for each plant an economical and practical limit of sludge concentration in the aerators, determined by the costs and facilities for the oxygenation of the mixed liquor. A detailed study has been made of the relation between the maximum mixed liquor concentration and the oxygenation capacity of the plant.

It is well-established that a normal respiration rate of activated sludge is maintained even at very low oxygen tensions, provided an oxygen tension-equilibrium is established between the individual sludge floc and the surrounding medium. Oxygen tension is thus much less of a limiting factor for respiration in the mixed liquor than turbulence, which continuously creates new surfaces for oxygen diffusion to the sludge flocs. Kessener (16) has defined the oxygenation capacity as the quantity of oxygen dissolved per hour for each cubic meter of aerator volume at a pression of 760 mm. and a temperature of 10° C., when the oxygen content of the water is 0 ppm. By using the method of oxidizing $Fe(OH)_2$ to $Fe(OH)_3$ the oxygenating capacity of the pilot plant (brush aeration) has been measured. The resulting oxygen uptake curves (Figure 6) serve to illustrate the data obtained with 9-cm.

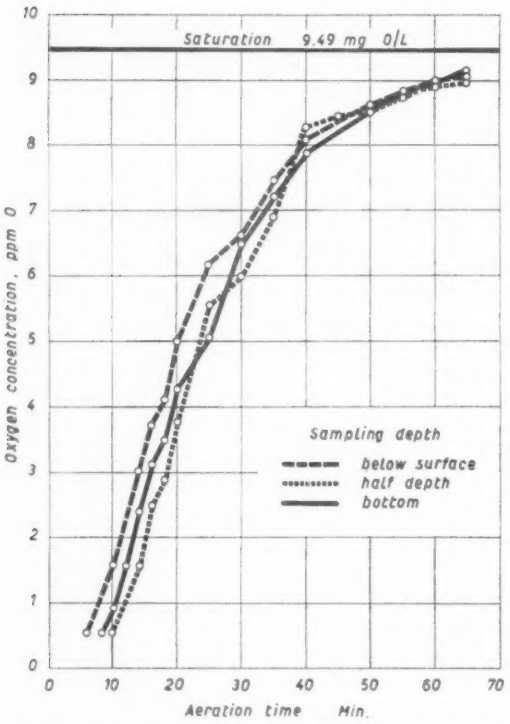

FIGURE 6.—Oxygen uptake at various depths in aeration basin; brush aeration at 178 r.p.m. and 9-cm. immersion depth.

immersion depth and 178-r.p.m. speed of the brushes. The oxygenation rate corresponds to a monomolecular reaction and thus the coefficient of the oxygen uptake is defined as

$$K = ln \frac{c_s - c_0}{c_s - c_\tau} \cdot \frac{1}{\tau - \tau_0}$$

In the foregoing example the following values of K have been found when τ is measured in hours:

Below surface	$K_{15.6°} = 2{,}916$ hr.$^{-1}$
Half depth	$= 2{,}883$
Bottom	$= 2{,}762$
Mean value	$2{,}854$ hr.$^{-1}$

The oxygenation capacity, W, of the aeration basin is then

$$W = K\, c_s \quad \text{g.O}_2 \text{ per cu. m. per hr.}$$

Obviously, W is directly proportional to c_s and thus is intimately dependent on the temperature of the water and on the atmospheric pressure. The value of K also must be corrected for different water temperatures (17) (18). The oxygenation capacity W_t can then easily be calculated at different temperatures. Based on the oxygen saturation values of water at the average atmospheric pressure of 728 mm. at the pilot plant, the values of W_t given in Table III are found.

The concentration of mixed liquor in the aerator, which can be kept in an aerobic state (that is, in equilibrium between oxygen consumption and oxygenation capacity), may now be estimated if the oxygen consumption of the sludge is known. In this calculation the oxygen transported by the

inflowing raw sewage is neglected, because this quantity is of slight significance in practice due to the generally low oxygen concentration.

The oxygen consumption of activated sludge at 25° C. has been measured regularly in different series of experiments (micromanometrically). The temperature coefficient of sludge respiration was also investigated several times. Without entering into the details, the following empirical relation was found for this coefficient:

$$\alpha = \frac{\log Q_{t1} - \log Q_{t2}}{t_1 - t_2}$$

where Q_{t_1} and Q_{t_2} are measured in units and α is the temperature coefficient of respiration of sludge (hr.$^{-1}$); Q_{t_1}, Q_{t_2} = sludge respiration at temperatures t_1 and t_2 (mg. oxygen per gram of suspended solids per hour; and t_1, t_2 = temperature, °C.

This equation does not agree with the relation of Van 'tHoff and Arrhenius, but it fits the observations much better. For the basal respiration of activated sludge values of α were found to be between 0.031 and 0.0315. Sawyer *et al.* (19) (20) in studies on respiration of activated sludge observed temperature coefficients of the same order of magnitude, even though another empirical formula was used for calculating α, and in spite of the fact that the method of respiration measurement was quite different from that used herein (the sludges used in their investigation showed respiration rates of only 8 to 12 mg. of oxygen per gram of suspended solids at 25°). The respiration rates of sludges at several temperatures with different basal respiration can thus be evaluated (Table IV).

With these data, it is possible to calculate the sludge concentrations in the mixed liquor, that are tolerable in the aeration basins at different sewage temperatures, provided that oxygen consumption of the mixed liquor and oxygen uptake are in continuous equilibrium. Aeration is performed with brushes revolving at 178 r.p.m. and with an immersion depth of 9 cm. The tolerable sludge concentration is

$$C_{max.} = \frac{W_t}{Q_t},$$

where Q_t is in mg. of oxygen per gram of suspended solids per hour at t°C. Figure 7 represents values of $C_{max.}$ for the mentioned respiration rates of sludge (including the whole range of respiration intensities observed until now) as a function of the sewage temperature. It is easy to conclude that for a temperature range in the plant between 9° and 16.5° the lower limit of sludge concentration in the mixed liquor is about 2,000 p.p.m. (highest

TABLE III.—Oxygenation Capacity of Pilot Plant: Brush Aeration at 178 R.P.M. and 3.5 In. Immersion Depth

Sewage Temp. (°C.)	C_t* (p.p.m.)	K_t (hr.$^{-1}$)	W_t† (g.)
5	12.19	2.387	29.2
10	10.77	2.599	28.0
15	9.56	2.809	26.9
20	8.66	3.014	26.1
25	7.83	3.224	25.2

* P.p.m. oxygen, under consideration of the tension of water vapor at t° C. and 728 mm. air pressure.

† Grams of oxygen per cubic meter per hour.

TABLE IV.—Respiration Rates of Activated Sludges of Different Basal Respiration at Various Temperatures

Temp. (°C.)	Oxygen Uptake of Sludge (mg./g./hr.)[1]		
	Basal Respiration at 25° C. =		
	15	20	25
5	3.60	4.80	6.0
10	5.15	6.85	8.57
15	7.35	9.80	12.2
20	10.6	14.15	17.7
25	15.0	20.0	25.0

[1] Milligrams oxygen per gram of dry solids per hour.

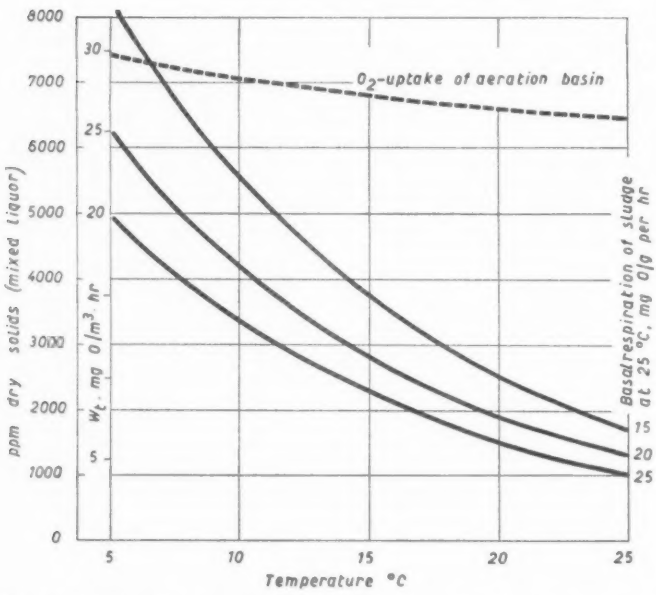

FIGURE 7.—Relationship between basal respiration of activated sludge and mixed liquor concentration at various temperatures, when the oxygen uptake of the aeration basin is as shown.

water temperature and highest respiration rate). The highest concentration may be about 5,000 to 6,000 p.p.m. (lowest temperature and respiration rate).

Comparing the sludge concentrations actually maintained in the experiments with the tolerable values according to Figure 7, it is found that in a considerable number of runs the mixed liquor concentration attained the limit value or even surpassed it for short periods. As the Zurich raw sewage carries in general about 1 to 2 p.p.m. of oxygen, no detrimental effects were observed due to excessive solids content, the lacking oxygen being supplied by the raw sewage. Furthermore the decreasing respiration rate of the sludge during the night produced a certain oxygen reserve until the peak loads of impurities in the morning again charged the sludge.

It is obvious that the environmental conditions, such as sewage temperature and sludge respiration rate, limited the possibility of increasing the sludge concentration in the experiments, due to the uniform maximum oxygenation capacity of the aeration system.

Costs of brush aeration at the plant may be estimated as follows. Power consumption of the 5.5-m. brush length (77-cu. in. aerator volume) totaled 1.48 kw. In this tank the oxygenation capacity at 10° C. and 728-mm. pressure was 28.3 g. of oxygen per cubic meter per hour, or 2,180 g. of oxygen per hour for the entire tank. Hence, 1.48 kw.-hr. of energy were required for 2,180 g. of oxygen, or 0.68 w. per gram of oxygen.

By increasing the length of brush per volume of aerator, the oxygenation capacity is increased considerably and the loading of the system may be increased in proportion. At the same time, the cost of aeration per gram of oxygen supplied decreases proportion-

ally. Pasveer (17) (18) has shown that a further development of the surface aeration systems with brushes seems, therefore, to be quite profitable.

Unfortunately, no figures are known on oxygenation capacities of larger sewage plants with compressed air aeration, which could be compared with the brush aeration plant. Imhoff (21) has, however, published data on air input per pound of B.O.D. removed at some American activated sludge plants. The power required for compressing these air volumes may be approximately estimated according to the assumption of Imhoff and Fair (22) that 1,000 cu. ft. per minute is equivalent to 4 hp. A basis for comparisons is then found when the energy requirements for removing 1 lb. of B.O.D. are calculated (Table V).

In Table V only those American plants with the highest B.O.D. loads, according to Imhoff (21), have been chosen. It is evident that smaller energy requirements are found for the brush aeration plant than for the compressed air installations. This agrees with Ridenour and Henderson (23), who compared two activated sludge plants, operated in duplicate, with brush and compressed air aeration, respectively. For the same purification standard, annual costs were smaller for the brush aeration plant. These tests were carried out at conventional plant loads. It would be highly interesting, therefore, to repeat them at high loads.

Inorganic Additions to the Sludge

As an early hypothesis it was suggested that the addition of fibrous asbestos to the mixed liquor would help in maintaining favorable operating conditions at high-load plants. This idea dominated the experiments for several years, during which 1 mg. of asbestos per liter of inflowing raw sewage was regularly added. Series I to IX were carried out in this way. As the effect of asbestos became more and more doubtful, an experiment was started (series X) with the special aim of determining the specific effect of adding asbestos. This series X (see Table VI) was started with the two duplicate pilot plants, in which identical operating conditions were most carefully maintained. Plant II was supplied with 1 p.p.m. of asbestos (added all at once in daily portions) as this has been the procedure in all earlier experiments. Plant I received no addition at all. In a second part of this experiment the amount of asbestos was increased to 20 p.p.m. The complete series of experiments was carried out in duplicate with two ranges of hydraulic load (74.5 to 164 gal. per

TABLE V.—Energy Requirements per Pound of B.O.D. Removed

Brush Aeration (Pilot Plant)				Compressed Air Aeration (U. S. plants)[1]			
Experiment	Load (lb. B.O.D./ 1,000 cu.ft./day)	Energy Consumed (kw.hr./lb. B.O.D. rem.)	Purif. Effect (%)	Plant	Load (lb. B.O.D./ 1,000 cu.ft./day)	Energy Consumed (kw.hr./lb. B.O.D. rem.)	Purif. Effect (%)
IX_{o1}	23	0.28	94	New York, Jamaica	100	0.18	75
X_1	87 to 106	0.12 to 0.13	91 to 93	U. S. plants, average	30	0.4	90 to 95
IX_{s2}	147	0.095	83	New York, Wards Isl.	67	0.19	94
X_2	191	0.077	82 to 83	New York, Bowery Bay	50 to 81	0.24	90

[1] Data from Imhoff (21).

TABLE VI.—Experimental Results; Mean Values of Observation Periods

Experimental series	IX		X_1				X_2		XI
Experiment number	a_1	o_1	a_1	o_1	a_2	o_2	a_3	o_3	o_3
Year	1948	1948	1948-9	1948-9	1949	1949	1950	1950	1949
(a) Plant Operation									
Aerator:									
Hydr. loading (g.p.d./cu. ft.)	83.5	20	75.5	75.5	75.5	75.5	161	164	167
Sludge recirculation (%)	64	74	68	65	64	58	36	36	52
Aeration time[1] (min.)	128	540	143	143	143	143	65	65	64
Var., day flow to night flow	2:1	2:1	1.83:1	1.83:1	1.83:1	1.83:1	1.83:1	1.83:1	1:1
Mixed liq. susp. sol.[2] (p.p.m.)	3,930	2,830	3,440	3,100	3,360	3,200	3,460	3,570	3,460
Ret. sludge susp. sol. (p.p.m.)	10,000	5,120	7,170	7,340	7,340	7,200	8,380	8,600	10,000
Sludge index, in liq.	374	179	362	294	559	433	273	270	332
Sl. respiration (g. 0/g. dry sol./hr.)	—	—	18.0	20.0	21.0	20.0	23.2	24.5	—
Asbestos added (p.p.m.)	1	0	1	0	20	0	1	0	0
Diss. oxygen, mixed liq.[3]	2.9	3.4	4.0	3.8	4.4	3.9	1.8[4]	1.7[4]	3.2[4]
Secondary clarifier:									
Surface loading (ft./hr.)	3.9	2.4	3.5	3.5	3.5	3.5	3.9	3.9	3.9
Det. time, theor. (min.)	120	200	132	132	132	132	122	122	120
(b) Analytical Results									
Raw sewage temp. (°C.)	15.4	15.6	10.1	10.1	9.8	9.8	14.1	14.1	11.0
pH, raw sewage	—	—	—	—	—	—	7.6	7.6	7.7
Total solids (p.p.m.):									
Raw sewage	543	543	651	651	622	622	549	549	384
Sec. clar. effluent	408	435	466	444	418	422	419	419	339
Volatile solids (p.p.m.):									
Raw sewage	321	321	270	270	238	238	222	222	139
Sec. clar. Effluent	248	238	153	116	114	113	137	140	115

[1] Raw sewage only.
[2] Measured at 2 PM or 4 PM.
[3] Measured at 8 AM or 7.30 AM.
[4] At 1 PM, 0.3, 0.3, and 0.9, respectively.

TABLE VI.—*Continued*

Experimental series	IX		X_1				X_2		XI
Experiment number	a_1	o_1	a_1	o_1	a_2	o_2	a_3	o_3	o_2
Year	1948	1948	1948–9	1948–9	1949	1949	1950	1950	1949
(b) Analytical Results.—Continued									
Suspended solids (p.p.m.):									
Raw sewage	61	61	78	78	75	75	151	151	96
Sec. clar. effluent	10	8	22	14	8	7	47	35	24
Oxygen cons., $KMnO_4$ (p.p.m.):									
Raw sewage	—	—	—	—	—	—	340	340	262
Sec. clar. effluent	—	—	—	—	—	—	120	126	79
B.O.D., 5-day (p.p.m.):									
Raw sewage	123	123	167	167	142	142	139	139	115
Sec. clar. effluent	13	8	16	16	11	10	24	25	32
Organic-nitrogen (p.p.m.):									
Raw sewage	10.9	10.9	9.9	9.9	9.0	9.0	7.6	7.6	8.8
Sec. clar. effluent	2.4	1.4	1.4	2.1	0.7	1.0	3.1	2.4	2.4
Ammonia-nitrogen (p.p.m.):									
Raw sewage	12.3	12.3	22.1	22.1	21.3	21.3	15.4	15.4	18.3
Sec. clar. effluent	9.5	2.4	18.4	18.3	17.0	17.4	13.7	14.2	16.1
Nitrite- and nitrate-N (p.p.m.):									
Raw sewage	0.4	0.4	2.0	2.0	1.5	1.5	0.6	0.6	2.5
Sec. clar. effluent	1.0	8.3	1.6	1.8	1.0	1.0	0.6	0.6	1.1
Total nitrogen (p.p.m.):									
Raw sewage	23.6	23.6	34.0	34.0	31.8	31.8	23.6	23.6	29.6
Sec. clar. effluent	12.9	12.1	21.4	22.2	18.7	19.4	17.4	17.2	19.6
Amino acids,[b] as N (p.p.m.):									
Raw sewage	0.44	0.44	0.48	0.48	0.47	0.47	—	—	—
Sec. clar. effluent	0.09	0.1	0.14	0.09	0.15	0.15	—	—	—
Total phosphorus (p.p.m.):									
Raw sewage	—	3.53	2.75	2.75	2.51	2.51	2.93	2.93	—
Sec. clar. effluent	—	2.84	1.64	1.54	1.39	1.34	1.66	1.57	—

[b] After hydrolysis of unfiltered samples.

TABLE VI.—*Continued*

Experimental series	IX		X_1				X_2		XI
Experiment number	a_1	$\bar{o}_1$	a_1	o_1	a_2	o_2	a_2	o_2	o_3
Year	1948	1948	1948-9	1948-9	1949	1949	1950	1950	1949
(b) Analytical Results.—Continued									
Organic carbon (p.p.m.):									
Before filtering:									
Raw sewage	—	—	67.3	67.3	53.2	53.2	82.1	82.1	—
Sec. clar. effluent	—	—	14.8	16.2	10.8	11.6	28.2	28.8	—
After filtering[6]:									
Raw sewage	—	—	37.7	37.7	29.3	29.3	20.9	20.9	—
Sec. clar. effluent	—	—	11.2	13.9	9.2	9.9	11.3	12.1	—
(c) Purification Effects									
B.O.D., 5-day:									
Load (lb./1,000 cu. ft./day)	86.3	23.1	105.7	105.7	90.0	90.0	191.3	191.3	202.0
Rem. (lb./1,000 cu. ft./day)	77.0	21.9	95.6	95.6	79.5	83.8	158.2	157.0	159.0
Reduction (%)	89	95	91	91	88	93	83	82	79
Oxygen consumed, $KMnO_4$:									
Load (lb./1,000 cu. ft./day)	—	—	—	—	—	—	467	467	364
Rem. (lb./1,000 cu. ft./day)	—	—	—	—	—	—	303	295	253
Reduction (%)	—	—	—	—	—	—	65	63	70
Total nitrogen:									
Load (lb./1,000 cu. ft./day)	16.5	3.94	21.9	21.9	20.1	20.1	32.5	32.5	41.4
Rem. (lb./1,000 cu. ft./day)	7.44	1.69	8.1	7.5	8.25	7.5	8.75	8.75	14.1
Reduction (%)	45	43	37	35	41	37	27	27	34
Organic nitrogen:									
Load (lb./1,000 cu. ft./day)	7.63	1.5	6.25	6.25	5.69	5.69	10.42	10.42	12.3
Rem. (lb./1,000 cu. ft./day)	5.94	1.38	5.38	4.82	5.19	5.0	6.2	7.06	9.0
Reduction (%)	78	92	86	77	91	88	60	68	73

[6] After filtering through membrane filters.

TABLE VI.—*Continued*

Experimental series	IX		X_1				X_2		XI
Experiment number	a_1	o_1	a_1	o_1	a_1	o_1	a_1	o_1	o_1
Year	1948	1948	1948–9	1948–9	1949	1949	1950	1950	1949
(*c*) Purification Effects.—*Continued*									
Organic carbon[7]:									
Load (lb./1,000 cu. ft./day)	—	—	42.6	42.6	33.7	33.7	113	113	—
Rem. (lb./1,000 cu. ft./day)	—	—	33.2	32.3	26.8	26.4	74	73	—
Reduction (%)	—	—	78	76	79	78	65	64	—
Total phosphorus:									
Load (lb./1,000 cu. ft./day)	—	—	1.75	1.75	1.56	1.56	4.03	4.03	—
Rem. (lb./1,000 cu. ft./day)	—	—	0.69	0.7	0.69	0.7	1.73	1.85	—
Reduction (%)	—	—	40	40	44	45	43	46	—
(*d*) Excess Sludge									
Quantity:									
Spec. vol. (gal./1,000 gal. sewage)	9.5	12.7	14.2	12.4	17.1	13.5	11.9	12.3	12.1
(gal./lb. B.O.D. rem.)	10.4	11.7	11.2	9.8	16.3	12.3	12.4	12.9	12.8
Total sol. (lb./1,000 gal. sewage)	0.79	0.65	0.77	0.76	1.06	0.84	0.78	0.83	1.08
(lb./lb. B.O.D. rem.)	0.87	0.60	0.62	0.61	1.02	0.76	0.81	0.87	1.15
Volatile sol. (lb./lb. B.O.D. rem.)	0.55	0.37	0.46	0.45	0.67	0.56	0.56	0.62	0.81
Composition:									
Total solids (p.p.m.)	10,000	6,120	7,170	7,340	7,340	7,200	8,380	8,600	10,000
Ash, dry solids (%)	37.0	38.8	25.0	26.2	34.3	26.0	30.6	28.3	29.8
Total nitrogen (%)	4.73	5.5	6.47	6.25	5.40	6.04	6.07	6.18	6.69
Organic carbon (%)	40.8	17.2	27.5	31.5	24.4	32.9	40.8	41.2	33.2
Total phosphorus (%)	1.34	1.32	1.59	1.60	1.67	1.29	1.37	1.32	1.49
Potassium (%)	0.56	0.53	0.58	0.53	0.50	0.51	0.35	0.36	0.54
Amino acid-N[8] (%)	2.54	4.65	3.19	3.99	3.01	4.32	3.04	3.56	3.25

[7] Unfiltered.

cu. ft. per day or 106 to 191 lb. B.O.D. per cu. ft. per day).

Figure 8 contains a few examples of sedimentation curves of the mixed liquor (samples always taken at the same time in both plants). No influence whatever on sludge properties could be found with an asbestos addition of 1 p.p.m. In the period with an addition of 20 p.p.m. (which was sufficient to maintain an asbestos concentration in the sludge of about 7 p.p.m., based on dry suspended solids) no special observations could be made for some time. But gradually the sludge index rose and it easily could be shown that the unwieldy character of the asbestos considerably hindered the thickening of the sludge in the final clarifier.

The values in Table VI demonstrate clearly the absolute similarity of the two duplicate plants in both experimental periods.

Due to the experience gained in series X, no more asbestos was applied in later runs and the results of the experiments remained of course, unchanged. Other additions were tentatively applied in short runs, but as with asbestos, no effect could be detected. This is in agreement with most of the others who investigated certain additions to activated sludge: for example, Jung (24) ferric hydroxide; Nesmejanoff (25), iron and aluminum salts; Hasetine (26), lime; Ely (27), clay; and Mohlman (28), clay, diatomaceous earth, cellulose fibers, etc. It is the opinion of the present author that addition of inorganic material to activated sludge is not only useless for the operation of an activated sludge plant treating normal sewage, but is even undesirable considering the increase of excess sludge volume and ash content.

Analytical Results

Reduction in B.O.D.

A principal aim of the experiments reported here was to determine a continuous relation between B.O.D. concentration of raw sewage, hydraulic load of the plant, and B.O.D. concentration of the final effluent. This relation was sought covering as broad a B.O.D. concentration and load range as possible. It is obvious that such a relation can have only a limited precision, since many variables inherent in every treatment process cannot be controlled. But with a sufficient number of experiments at hand, carried

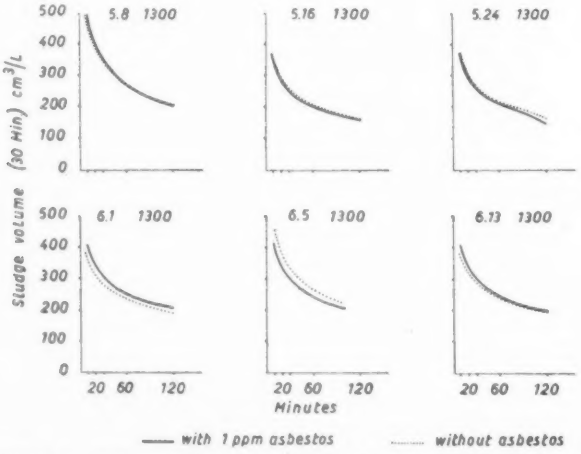

FIGURE 8.—Sedimentation curves of mixed liquor in runs X_{a2} and X_{o2}.

out at different levels of certain variables, it should be possible to correlate the results with the main variables. Twenty nine experiments merited evaluation. First of all, using the method of multiple correlation, the influence of the main variables was tested. These included the influence of temperature, sludge concentration in the mixed liquor, B.O.D. of the raw sewage, and hydraulic load of the aerator on the B.O.D. of the final effluent. Averages of entire experimental periods of the parameters mentioned were used for the calculations. No significant influence of the mixed liquor concentration on the final effluent B.O.D. could be established; a result which was to be expected due to the small variations of this parameter in the experiments. Correlation of effluent quality with sewage temperature was only slightly significant and was not found worthy of further investigation. This is rather amazing, considering, for instance, the large increase of sludge respiration between 9° and 16° C. (Table IV), the normal temperature limits of the Zurich sewage. It seems that in comparing only the average values of longer experimental periods, it is impossible to recognize significant minor influences, such as temperature, due to the action of a large number of other variables. The other two parameters—B.O.D. of the raw sewage and hydraulic load—proved, however, to be highly significant in this first test. For this reason the following procedure was adopted for further evaluations of the observations:

The 29 runs were arranged into groups of similar hydraulic load (giving groups of 30, 78, 123, and 164 gal. per cu. ft. per day). Within these groups the individual observations of raw-water B.O.D. (daily means) were divided into classes having 20-p.p.m. B.O.D. class intervals. The B.O.D. values of plant effluents corresponding to the raw-water values in each class were then averaged and correlated with the class means of raw-water B.O.D.'s. It is then found that within the range of observations and within each group of hydraulic loads, there exists a good linear regression between raw-water B.O.D. and effluent B.O.D. A certain amount of dispersion is inevitably included in these correlations, due to the variation in the influences of different factors between the experiments. From the regression lines found by this method it was possible to construct Figure 9, which now contains the desired relation between effluent B.O.D., hydraulic load, and raw-water B.O.D. Figure 9 is only valid, however, for the operational conditions of the experiments, the most important of which is a sludge concentration in the mixed liquor of about 3,000 p.p.m. (with loads above 70 gal. per cu. ft. per day or 75 lb. B.O.D. per 1,000 cu. ft. per day.) It should be emphasized that the precision of Figure 9 should not be overestimated, due to the many uncontrollable variables. It does, however, give the most probable correlation between the daily mean of plant influents and effluents at a given load and under given operating conditions.

It is of some interest to compare these observations with the results of other authors, although it should not be forgotten that systematic pilot plant studies of high-rate activated sludge treatments have not been published previously. Restricted comparisons are possible, however, with the experiments of Okun (7) and Smith (8), taking into account the fact that the dimensions of the aeration basins of the laboratory plants used by these two authors were more than a thousand times smaller than those used in these studies. Figure 10 shows the relations between B.O.D. load and B.O.D. reduction of the activated sludge process according to Greeley (3) and Okun (7), respectively. In this figure have been incorporated the corresponding relations for raw-water concentrations

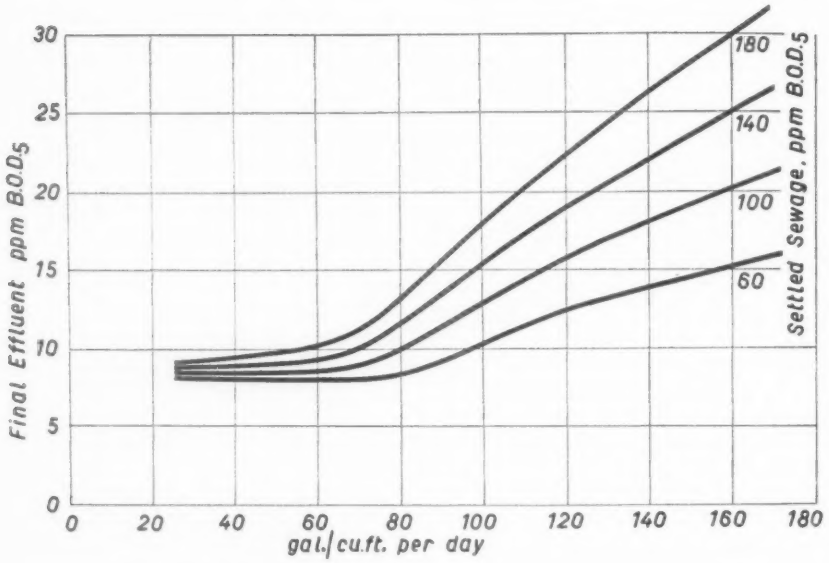

FIGURE 9.—Relationship between hydraulic load of aeration basin and B.O.D. concentration of final effluent at various concentrations of raw settled sewage. The diagram is valid for 3,000 p.p.m. suspended solids in mixed liquor at loadings of more than 60 to 80 g.p.d. per cubic foot and not more than 150 p.p.m. suspended solids in the settled raw sewage. The curves give the most probable effluent concentrations (daily averages).

of 120 and 180 p.p.m. B.O.D., deduced from the current experiments. Furthermore, mean values of entire experimental runs at raw-water concentrations between 120 and 180 p.p.m. have been marked. Figure 10 indicates that the author's observations are consistently better than the assumptions of Greeley, and that for higher raw-water concentrations they are quite close to those of Okun. It appears, however, that the computation method chosen by Greeley and Okun is somewhat unsatisfactory, because the influence of the hydraulic load on plant performance cannot be demonstrated explicitly.

In the interesting study made by Smith (8), B.O.D. reduction in experiments at relatively high loads is expressed as a function of a loading parameter, proposed by Fair and Thomas (29). This loading parameter has been calculated for each of the author's runs according to the definition given by Smith. Mean values of B.O.D. reduction of the averages of entire experimental periods are shown in Figure 11 as a function of the loading parameters of the respective experimental runs. The individual results have been divided into experiments with sludge concentrations in the mixed liquor above and below 3,000 p.p.m., respectively. The function calculated by Smith also has been incorporated in Figure 11, which may be interpreted as follows:

Runs with sludge concentrations of at least 3,000 p.p.m. form a curve similar in shape to that of Smith, but at a considerably higher level. These experiments have been carried out at full utilization of oxygenation capacity of the aeration mechanism; that is, at sludge concentrations which just permitted the maintenance of an aerobic state throughout the plant. When the

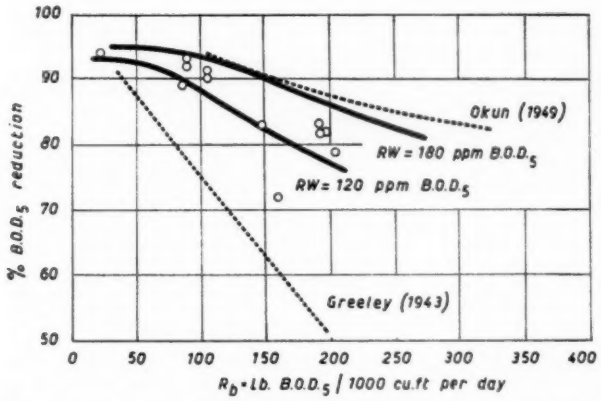

FIGURE 10.—Comparison of pilot-plant removals with previously published results. Single points represent average results of experimental series with sewage B.O.D. concentrations between 120 and 180 p.p.m. (Curves for 120 and 180 p.p.m. B.O.D. from Figure 9.)

sludge concentration decreased, the plant efficiency also dropped. The B.O.D. reduction, however, remained on a higher level than in the experiments of Smith.

It is not at all surprising that discrepancies arise between the present results and those of Okun and Smith, the experimental conditions in the respective investigations being so widely different. But because, in general, small laboratory installations give higher yields than pilot or full-scale plants, it is to be expected that B.O.D. reduction in the pilot plant would be markedly inferior to that in the experiments of Okun or Smith. As this is not the case, it is concluded that in the present experiments the potential purification capacity of the pilot plant has been utilized more extensively than by the other investigators.

Comparing the results of these experiments with those of Setter (4)(5)(6) in the Jamaica plant of New York City, considerable differences requiring

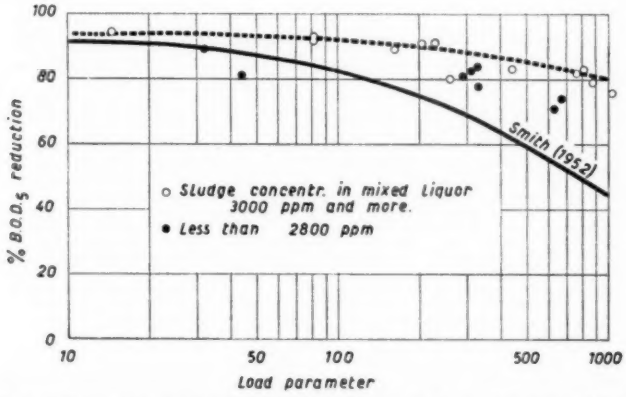

FIGURE 11.—Comparison of pilot-plant removals with previously published results. Individual pilot-plant runs are grouped according to the respective mixed liquor concentration.

TABLE VII.—Effect of Eutrophication in a Model River*

Concentration in River Water		Weight of Organism Growth† (g.)	Predominant Organisms
Total Nitrogen (p.p.m.)	Total Phosphorus (p.p.m.)		
21.8	1.4	19.4	Diatoms
7.4	0.4	12.8	and some
1.4	0.07	8.5	*Cladophora*

* From Wuhrmann (31) (32).

† After 33 days (winter 1946–47), t approximately 4° C., in grams of organic matter per square foot.

explanation are again evident. In New York, B.O.D. eliminations in the range of 66 to 77 per cent have been observed at aerator loads of 37 to 100 lb. B.O.D. per 1,000 cu. ft. per day. Plant efficiency in the pilot plant experiments must apparently be considered higher. The discrepancy is easily explained by the very low solids concentration (600 to 700 p.p.m.) in the mixed liquor of the Jamaica plant. Further comparisons should, therefore, be based on an equal parameter (as, for instance, power consumption per pound of B.O.D. removed). According to Table V, about 0.18 kw.-hr. are consumed per pound of B.O.D. removed at the Jamaica plant. The corresponding value of B.O.D. removed, in the current experiments is 0.07 to 0.12 kw.-hr. per pound which is considerably lower. It seems, therefore, that in the experiments of Setter the optimal concentration of the mixed liquor with regard to purification efficiency and power consumption would have been higher than that actually applied.

Elimination of N and P from Sewage

It has been pointed out that the elimination of eutrophicating compounds of nitrogen and phosphorus is a primary requirement of sewage purification in many localities, in view of the dangers of secondary pollution of watercourses and lakes due to excessive growth of organisms. In the United States it was primarily Sawyer (30) who drew attention to the eutrophication of streams and lakes by treated or untreated sewage. This problem met with much more interest in Switzerland; observations on the amount of nitrogen and phosphorus retained in a purification plant, as well as eutrophication studies in model rivers, were systematically undertaken. For instance, it is easy to demonstrate quantitatively the fertilizing effect of purified sewage in experiments with model rivers (31) (32) (33). When the

TABLE VIII.—Nitrogen Elimination in the Activated Sludge Process

Pilot Plant Exper. No.	R_A (Aerator) (gal./cu.ft./day)	Total N in		N-Elimination	
		Aerator Influent (p.p.m.)	Final Effluent (p.p.m.)	(p.p.m.)	(%)
IX_o	20	23.6	12.1	11.5	49
VI_o	30.6	32.7	16.4	16.3	50
X_{o1}	75	34.0	22.2	11.8	35
IX_{a2}	118	23.7	13.7	10.0	42
X_{o2}	164	23.6	17.2	6.4	27
XI_{o2}	168	29.6	19.6	10.0	34
Chicago, SW[1]	19.5	20.7	11.2	9.5	46
Jackson, Mich.[1]	25	21.1	15.8	5.3	25
Chicago, N[1]	27	19.1	10.6	8.5	44
Chicago, Calumet[1]	28	19.9	14.2	5.7	29

[1] Annual averages from 1946 annual reports.

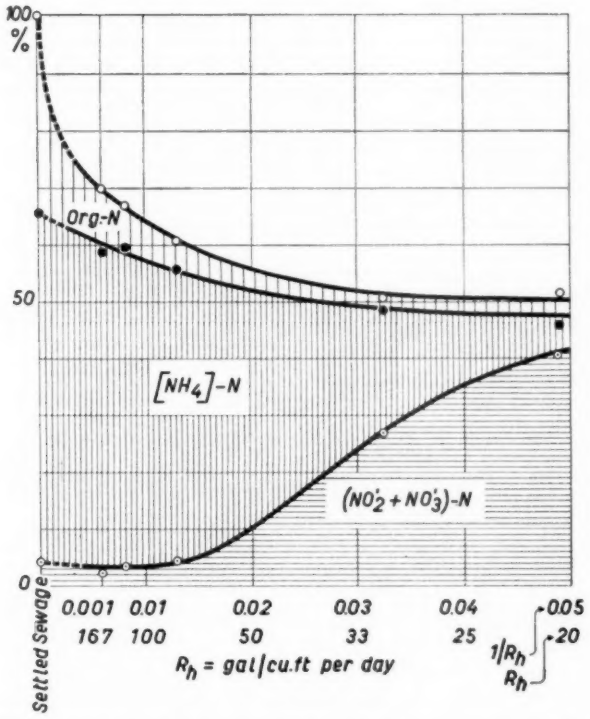

FIGURE 12.—Change in relative concentration of nitrogen compounds in sewage by activated sludge treatment (settled raw sewage = 100 per cent).

total mass of organisms having developed per square meter of river bed after a certain period of river flow was estimated (for example, volatile matter per square meter of river bed), the results given in Table VII were observed in the winter of 1946–47.

Nitrogen Elimination—Nitrogen in raw sewage (mostly as ammonia-nitrogen or urea) may be eliminated either by fixation in sludge (leaving the plant in the excess sludge) or by bacterial denitrification (escaping as gaseous nitrogen). In a number of experiments it was attempted to establish complete nitrogen balances measuring the total inflowing nitrogen as well as the total amount of nitrogen output in effluent and excess sludge. Table VIII contains observations on nitrogen elimination in a number of runs, together with figures from American plants computed from annual operation reports. It is remarkable that nitrogen elimination increases in general with decreasing plant load, but an asymptotic limit of 50 per cent elimination has never been surpassed. In comparing the current results with those of large American plants, the agreement is striking.

As the percentage of the different nitrogen components of the total nitrogen in the raw sewage of the pilot plant is practically constant, all N values have been calculated on the basis of the total nitrogen in the raw sewage (= 100 per cent). Again arranging the experiments in load groups and averaging the percentages of the nitrogen components in the effluents of the experiments in each load group, results in Figure 12 when the reciprocal of

TABLE IX.—Nitrogen Deficits in Activated Sludge Experiments

Exper.	Total N to Plant (lb./day)	Total N leaving plant with			Balance	
		Effluent (lb./day)	Excess Sludge (lb./day)	Total (lb./day)	(lb./day)	(% of Infl.)
IX_{s1}	45.0	24.6	8.5	33.1	−11.9	−26
IX_o	27.0	15.4	4.9	20.3	− 6.7	−25
X_{o1}	58.4	38.1	9.8	47.9	−10.5	−18
X_{s1}	58.4	36.8	10.3	47.1	−11.3	−19
X_{o2}	54.6	33.3	10.5	43.8	−10.8	−20
X_{s2}	54.6	32.1	11.8	43.9	−10.7	−20
X_{o2}*	44.0	32.1	11.5	43.6	− 0.4	− 1
X_{s2}*	44.0	32.6	10.6	43.2	− 0.8	− 2
XI_{o2}*	56.4	37.2	16.6	53.8	− 2.6	− 5

* Aeration very scanty in these runs.

hydraulic load is taken as the second parameter. This diagram demonstrates the relative concentration change of total nitrogen and of certain nitrogen components during activated sludge treatment of Zurich's sewage as a function of plant load. The figure, again, is only an approximation insofar as the differences between the individual experiments are more or less eliminated by the computing procedure adopted. The facts observed in the course of the many years of pilot-plant studies are, however, expressed quite satisfactorily. It may be seen that most of the nitrogen which is eliminated is of organic nature (about one-half or one-third of it on account of the suspended solids in the raw sewage). But the concentration of total inorganic nitrogen also decreases, at least in experiments with long aeration periods. It is to be remembered that complete elimination of the primary suspended solids in the raw sewage could account only for a nitrogen elimination of about 20 to 30 per cent of that actually observed. It must be concluded, therefore, that most of the nitrogen removed from sewage in the course of the activated sludge treatment comes from the dissolved organic or inorganic components.

Of course, a considerable part of the nitrogen compounds eliminated are transferred to the solids of the activated sludge. Nevertheless, complete nitrogen balances of experiments conducted under especially careful analytical control demonstrate striking nitrogen deficits (Table IX). In most of the runs of Table IX the nitrogen deficits account for nearly one-half of the total nitrogen loss of the purification process. Three runs show amazingly low deficits. In these experiments the oxygen tension in the mixed liquor was especially low (less than 15 mm.) Until now no satisfactory explanation for the nitrogen deficits has been found. Bacterial denitrification would be the most likely hypothesis, but further evidence is needed to support this assumption.

Elimination of Phosphorus—This problem has been studied in a limited number of experiments only. Table VI contains those results regarded as sufficiently reliable to be published. About 40 to 45 per cent of the total phosphorus of the raw sewage is uniformly eliminated in the activated sludge treatment by transfer to the excess sludge. As estimations of phosphorus are not performed regularly in current plant supervision, a comparison of the experimental values with those of large plants was not possible. Jenkins and Lockett (34) have indicated, however, that 46 to 60 per cent of the phosphorus in unsettled sewage may be

recovered in the sludge after sedimentation and subsequent biological treatment. After deduction of the mean percentage of phosphorus in the primary sludge, the elimination limits given by Jenkins and Lockett are of the same order of magnitude as the author's observations.

Sludge Properties and Production

Table VI contains the most important quantitative data of the experiments, chosen as examples for this paper. No special remarks are necessary except, perhaps, an indication as to the sludge respiration values. Sludge respiration has been measured by micromanometric methods more or less regularly since 1947. Almost 100 per cent of the sludge samples from the high-rate experiments have shown respiration values of at least 18 mg. of oxygen per gram per hour at 25° C. At conventional plant loadings, sludge respiration was in general considerably lower (that is, 11 to 16 mg. of oxygen per gram per hour). Unfortunately, respiration values at the low plant loadings are too scarce in the experimental work to establish a correlation between plant loading and sludge respiration. As far as reliable data from other plants have been published, however, it can be assumed that with decreasing plant load, sludge respiration also decreases to a certain extent. This may be due to the increasing sludge age, as experiments by the author and by Ruchhoft *et al.* (35)(36) show that continuous sludge aeration leads to a rapid decrease in oxygen consumption.

Notwithstanding the large number of experiments in a wide range of conditions, it is rather difficult to extract from the experimental data a general rule for excess sludge production. Heukelekian *et al.* (37) published a formula for the calculation of excess sludge volume as a function of mixed liquor concentration and B.O.D. loading of an activated sludge plant. Computation of the experimental observations according to this formula leads to no reasonable result. Some correlation was found, however, between volatile matter in excess sludge and B.O.D. loading of the aerator (Figure 13) or of sludge age (Figure 14), respectively. Both relations are rough approximations. Volatile solids production correlated with sludge age gives, nevertheless, an impression of the "self consumption" of sludge during prolonged aeration and is a logical support of the previously mentioned

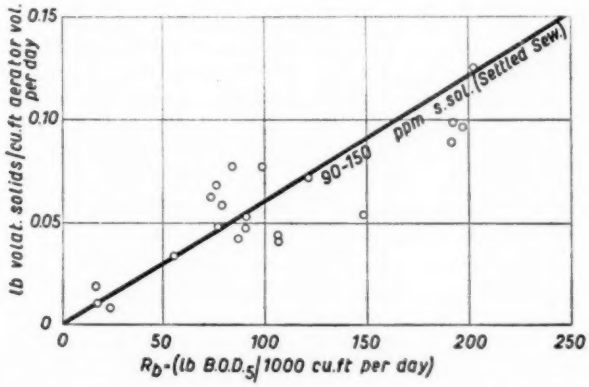

FIGURE 13.—Excess sludge volatile solids production as a function of plant loading (pounds B.O.D. per 1,000 cu. ft. per day).

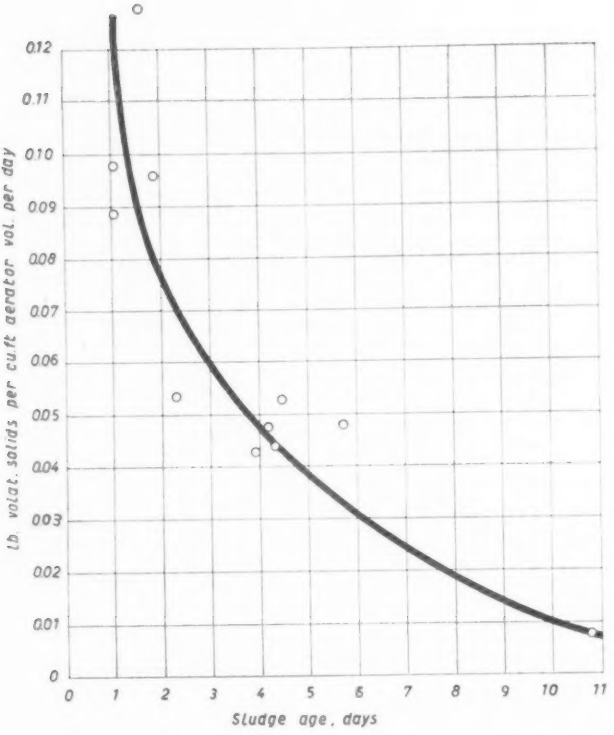

FIGURE 14.—Excess sludge volatile solids production as a function of sludge age (as defined by Gould).

reduction of respiration of "old" sludges.

No continuous relation could be found for the connections between plant operation and sludge composition, although certain correlations seem to exist. For instance, the organic carbon in sludge is apparently correlated to sludge age in much the same manner as is production of volatile solids (Figure 14). But as a rule, sludge composition was found to be rather uniform as far as nitrogen, phosphorus, and potassium are concerned.

A much more exacting experimental technique would be necessary for the detection of direct relationships between sludge composition and character of sewage or different operational data of the plant.

Conclusions

The pilot-plant studies, carried out on a technical scale, have shown that with rather short aeration periods—that is, at hydraulic loads up to 164 g.p.d. per cubic foot—B.O.D. reductions of at least 80 per cent can be achieved with settled domestic sewage, provided that there is a sufficient concentration of solids in the mixed liquor. As fairly low oxygen tensions are required throughout the plant for maintaining a healthy sludge, costs for aeration are considerably lower than for low-load plants. It is not yet clear how far the aeration period can be

reduced without detrimental effects on effluent quality, the aeration facilities of the pilot plant allowing only sludge concentrations up to about 3,000 to 3,500 p.p.m. It may be that the breakdown of certain compounds in sewage needs a minimum time regardless of the amount of sludge applied. Further investigation of this problem is required, in which the effluent qualities should not only be estimated with parameters such as B.O.D., organic nitrogen, etc., but also by tests under natural river conditions. The latter subject is discussed in a later paper of this series.

It is clear that the maximum solids concentration permissible in the mixed liquor depends on the aeration facilities of a plant, or more precisely on its oxygenation capacity at a given power input. Together with respiration rates of the sludge, it is possible to make an approximate estimation of the sludge concentration which can be kept in an aerobic state.

The results of the experiments reported here compare quite favorably with those of Okun (7), Smith (8), Setter (4)(5)(6), Ullrich and Smith (9), and Pasveer (17)(18)(38), B.O.D. reductions up to 160 to 170 lb. per 1,000 cu. ft. per day being achieved. Energy requirements less than 0.1 kw.-hr. per pound of B.O.D. at the higher loads have been observed. Brush aeration (Kessener system) has thereby proved very efficient, although its application may be limited to smaller plants only.

It was possible to establish empirically a continuous relation between hydraulic load, B.O.D. of the raw sewage, and probable B.O.D. of the plant effluent. This relation indicates that neither the hydraulic load nor the concentration of the raw sewage have a marked effect on effluent quality within certain limits, provided an adequate sludge concentration is maintained. It may be, therefore, that some of the special operation recommendations (tapered aeration, step aeration) which have been proposed for low-load plants in the past few years would only prove their full value at much higher load ranges than those investigated at the respective plants.

Special attention was paid to the elimination of nitrogen and phosphorus, due to their importance in the receiving water bodies (eutrophication). Maximum elimination rates of about 45 to 50 per cent have been found at low hydraulic loads, this reduction decreasing slowly with decreasing aeration periods. Due to the fact that the content of organic carbon in domestic sewage is much too small to bind more nitrogen in sludge than is presently actually achieved, the problem of bacterial denitrification in the activated sludge process merits careful consideration.

As far as plant operation is concerned, high-rate treatment plants are as stable as conventionally operated ones. Inorganic additions (fibrous asbestos has been tried for some time) are apparently of no significant value. Return sludge volume however, was somewhat higher at short aeration times (up to 50 per cent). Excess sludge volumes amounted to 1.2 to 1.5 per cent of the raw-water influent; that is, to about the same percentages as in low-load plants.

Acknowledgments

The experiments reported herein were made possible only by the close cooperation of the Biological, Chemical, and Engineering Departments of the Institute. Special thanks are due to Prof. W.v. Gonzenbach, Prof. E. Meyer-Peter, and Dr. U. A. Corti, who initiated the erection of the pilot plant and supervised the investigations during their progress.

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INFILTRATION CONTROL DATA WANTED

The Committee on Infiltration Control Practices of the Pacific Northwest Sewage and Industrial Wastes Association earnestly requests replies to the following questions, and/or comments from engineers, contractors, materialmen, or others, who are interested in and wish to contribute to the improvement of sewer construction practices. Replies may be simply keyed to the designating numbers, and should be addressed to: Leland L. Sphar, Chairman, Public Works Engineer, City of Olympia, Wash.

1. Summary of your procedure in determining infiltration allowance for design, and statement of allowance you have used in typical designs.
2. What infiltration limits are specified in your construction contracts?
   (a) Is excess infiltration allowed in a particular length of sewer if that length is not thereby overloaded and the over-all allowable infiltration in the system is not exceeded?
   (b) When correction of excess infiltration is required, how do you determine the exact location of the leakage?
3. What kind of pipe and joint construction do you specify?
   (a) What has been your experience with other types of pipe and joints; what can you state as to relative efficiency and in-place costs?
4. Do you measure infiltration as part of your inspection procedure?
   (a) What method do you use to simulate wet weather conditions so that your measurement will approximate actual infiltration which may occur?
   (b) Describe measuring devices employed.
5. How do you enforce infiltration limits specified?
6. Can you furnish any data on infiltration as measured in completed systems?
7. What is your procedure on side sewer construction at time of main construction? At subsequent times?
   (a) What allowance do you make for infiltration from side sewers and what control if any do you have over the amount of such infiltration?
8. Is there some phase of the infiltration problem that you feel should be covered, other than included herein?
9. If you are a manufacturer of pipe or joint materials, any data that can be furnished relative to installations of the product are welcome.
10. If you are a contractor, comments are desired as to the practicality of infiltration control practices you have experienced, and your recommendation.
11. Can you furnish any references to other work on this subject in textbooks, magazines, theses, etc?

The reply should carry the respondent's name, title, organization, and address. Each contributor is to be furnished a copy of the Committee's findings.

RESEARCH ON ACTIVATED SLUDGE

III. Distribution of Oxygen in Activated Sludge Floc

By A. Pasveer

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Sewage purification, as in the activated sludge process for example, may be regarded as a reduction of the biochemical oxygen requirement of the water. In order to study the factors which determine the rate of the purification process, it is first necessary to make a study of the factors that influence the rate of the biochemical oxidation process.

Besides the rate of supply of oxygen to the floc there are a number of other factors which exert an influence on the rate of biochemical oxidation, such as temperature, nature of the bacterial flora, and composition of the sewage. In the following only the rate of supply of oxygen to the floc is dealt with.

Several Sub-Processes

Oxygen is absorbed from the air into the water, from which it finds access to the floc partly by the process of diffusion; it penetrates the floc by diffusion and becomes bound in the floc. It is necessary, therefore, to consider the following factors:

1. Rate of the diffusion process as a result of which oxygen is introduced into the liquid from the air (rate I).
2. Rate of diffusion from the water to the boundary of the floc (rate II).
3. Rate of diffusion in the floc (rate III).
4. Rate at which oxygen, after penetrating the floc, becomes bound in the latter (rate IV).

The rate of the entire process of biochemical oxidation is determined by the sub-process that takes place at the lowest rate. The question is whether, in the activated sludge process as conducted at present in sewage purification systems, the process of biochemical oxidation in the floc is the factor that decides the rate of purification or whether the limiting factor is to be found in one of the diffusion processes that determine the rate of supply of oxygen to the floc. An effort is made in the following to throw light on this point.

Rate of Oxygenation of Water

The report of a research on the rate of oxygenation of water has already appeared (1) (2). A much higher rate of oxygenation than has been achieved in practice up to the present can be realized in a simple manner.

Rate of Supply of Oxygen to the Floc

The rate at which oxygen can penetrate the floc depends upon what takes place in the floc—that is, upon rates III and IV and upon the supply of oxygen from the water to the boundary of the floc (rate II). These rates need to be studied in their mutual relationship. For this purpose use is made of the following additional symbols or supplementary definitions:

c = concentration of oxygen:
c_m = at center of floc;
c_p = in water/floc interfacial surface;
c_v = in liquid mass containing floc;
c_x = mean concentration in part of floc containing oxygen;

h = depth to which oxygen can penetrate the floc;
K = a constant;
k = diffusion constant of oxygen in water;
$n = 1/t'$;
Q_d = amount of matter (oxygen) diffused
Q_1 = quantity of oxygen that becomes bound in the floc;
r = radius of floc;
t' = hypothetical time of subsistence, in seconds, of static water/floc interfacial surface;
α = amount of oxygen, in grams, which becomes bound per second in 1 c.c. of floc volume when the oxygen concentration is 1 g. per c.c. ($= K\beta$);
β = concentration of organic matter, for this purpose assumed to be constant.

In the mathematical treatise examination is made of the state of equilibrium existing between the oxygen diffusing into the floc and the oxygen that becomes bound as a result of biochemical oxidation, in a number of states of turbulence. There are two possible cases to be considered in this connection; namely,

(a) The case in which the entire floc contains oxygen; and
(b) The case in which a part of the floc contains no oxygen.

Entire Floc Contains Oxygen

When the entire floc contains oxygen the amount of oxygen diffused from the liquid to the boundary of the floc is*

Q_d per floc per sec.

$$= 4\pi r^2 n\, 2\,(c_v - c_p)\sqrt{\frac{kt'}{\pi}} \quad \ldots (1)$$

For diffusion from the interfacial surface inward,

Q_d per floc per sec.

$$= 4\pi r^2 \frac{c_p - c_m}{r} k \quad \ldots (2)$$

The quantity that becomes bound in the floc is

Q_1 per floc per sec.

$$= \frac{4\pi r^3}{3} \alpha \frac{4c_p + c_m}{5} \quad \ldots (3)$$

in which $\frac{4c_p + c_m}{5}$ is the mean oxygen concentration in the floc. However,

$$c_m = c_p \frac{15k - 4\alpha r^2}{15k + \alpha r^2} \quad \ldots \ldots (4)$$

because $Q_d = Q_1$ (that is, Eq. 2 = Eq. 3), Also, because the values of Q_d in Eqs. 1 and 2 must be equal,

c_p (as percentage of c_v)

$$= \frac{100}{1 + \frac{2.5\alpha r}{15k + \alpha r^2}\sqrt{\pi k t'}} \quad \ldots (5)$$

Eq. 5 thus indicates, for a given value of c_v, in what way c_p depends upon the degree of turbulence, t'; the rate of biochemical oxidation, α; the radius of the floc, r; and the diffusion constant of oxygen in water, k. This relationship only holds good for $\alpha < \frac{15k}{4r^2}$. For larger values of α a part of the floc is free from oxygen.

Only a Part of Floc Contains Oxygen

For diffusion from the interfacial surface inward when only a part of the floc contains oxygen,

$$Q_d \text{ per floc per sec.} = 4\pi r^2 \frac{c_p - c}{h} k \quad \ldots (6)$$

Similarly the quantity bound biochemically is

Q_1 per floc per sec.

$$= \left\{\frac{4}{3}\pi r^3 - \frac{4}{3}\pi (r - h)^3\right\} \alpha\, c_x \quad \ldots (7)$$

For known values of r and h, c_x can be expressed in terms of c_p and α can be calculated by setting Eq. 6 = Eq. 7.

This calculation has been made for sizes of floc ranging from 50 to 2,000 μ.

* For use of Stefan's diffusion formula and the meaning of t' and n, see reference (1).

and for values of h ranging from 50 to 500 μ. (Table I and Figure 1).

When r and α are given, the depth h to which the oxygen will penetrate the floc can be read from Figure 1. This depth is independent of c_p.

It can furthermore be deduced, from Eq. 1 = Eq. 6, that

$$c_p \text{ (as percentage of } c_r) = \frac{100}{1 + \sqrt{\frac{\pi k l'}{2h}}} \quad . . (8)$$

in which the value found for h can be inserted.

The position is, therefore, that when α is known it is possible to calculate, for different sizes of floc in different states of turbulence, what part of the floc contains oxygen and what the mean concentration is in this part. The question arises, however, as to what is known concerning the value of α.

In the case of an aeration tank containing activated sludge and having an oxygenation capacity of 50 g. per hr. per cu. m., it is known that where it enters the tank the oxygen content of the mixed liquor may be in the neighborhood of 1 to 2 mg. per liter. It thus follows that the speed at which the oxygen becomes bound will also be of the order of 50 g. per hr. per cu. m. Taking the volume of floc as 10 per cent, this means that the amount of floc present per cubic meter amounts to 10^5 ml. At an oxygen concentration of 2 p.p.m., the rate of binding of oxygen is $10^5 \times 2.10^{-6} \times 3{,}600 \times \alpha$ grams of oxygen per hour. This quantity is equal to 50 g. per hr. per cu. m., from which a value of 0.07 can be calculated for α. For purposes of simplicity, let it be assumed for the time being that α has a value of about 0.1.

For $\alpha = 0.1$, a calculation was made for the distribution of oxygen in the floc. For various states of turbulence and for different sizes of floc values of c_p and c_m were calculated for the smaller floc and c_p and $(r - h)$ for the larger. Furthermore, the volume of the floc containing oxygen was calculated and the mean oxygen concentration in that volume expressed in terms of c_p. The last two values do not vary with variation of turbulence.

With the aid of the foregoing values a calculation was also made of the relative rate of biochemical oxidation for $\alpha = 0.1$ and given values of r and l'. The rate of biochemical oxidation = 100 if the oxygen concentration in the entire floc is equal to c_r.

The results are set forth in Table II, which indicates the following:

1. When $\alpha = 0.1$ the oxygen does not penetrate the floc further than to about 200 μ. This depth of penetration is independent of the oxygen concentration in the interfacial surface and only slightly dependent upon the size of floc.
2. For larger sizes of floc the percentage of active floc volume is lower.
3. For larger sizes of floc the mean oxygen concentration of the part containing oxygen is lower.
4. In the case of high turbulence the size of floc has little effect upon the

TABLE I.—Rate of Biochemical Oxidation for Various Sizes of Floc and Depths of Penetration

Depth, h (μ.)	Biochemical Oxidation Rate (g./c.c./sec.)							
	r = 2,000 μ.	r = 1,000 μ.	r = 500 μ.	r = 400 μ.	r = 300 μ.	r = 200 μ.	r = 100 μ.	r = 50 μ.
50	1.20	1.22	1.27	1.27	1.32	1.38	1.61	2.25
100	0.31	0.32	0.34	0.34	0.355	0.40	0.56	—
200	0.081	0.083	0.092	0.10	0.11	0.14	—	—
300	0.036	0.039	0.047	0.052	0.063	—	—	—
400	0.021	0.023	0.03	0.035	—	—	—	—
500	0.014	0.016	0.023	—	—	—	—	—

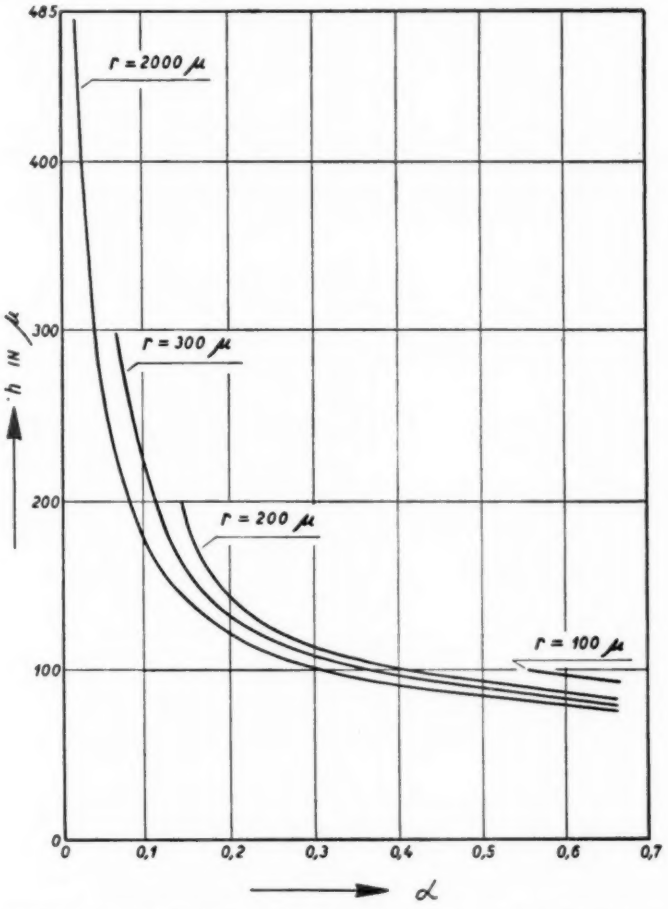

FIGURE 1.—Relation between size of floc, *r*, rate of biochemical oxidation, α, and penetration of oxygen, *h*.

concentration of oxygen in the interfacial surface. In the case of low turbulence the concentration of oxygen in the interfacial surface is considerably lower for the larger sizes of floc.

5. The relative rate of biochemical oxidation decreases as a result of insufficient supply of oxygen to the floc according as the particles of floc are of larger size and turbulence is less intense.

In connection with the foregoing it should be borne in mind that the size of floc depends, in general, upon the intensity of turbulence (the higher the intensity of turbulence the smaller the floc).

Conclusions

The foregoing theoretical considerations show that high intensification of turbulence in the mixed liquor may be a most influential factor in promoting the transfer of oxygen to the floc and thus increasing the rate of biochemical oxidation. With high turbulence the size of floc will become smaller and a

TABLE II.—Distribution of Oxygen in Floc and Comparative Rates of Biochemical Oxidation, for Varying Sizes of Floc and Conditions of Turbulence When $\alpha = 0.1$

Size of Floc, r (μ.)	Independent of Turbulence, n			$n = 100$*			$n = 10$			$n = 1$			$n = 1/4$			$n = 1/10$			$n = 1/100$†		
	Distance $r-h$‡ (μ.)	Volume Where Conc. $O_2>0$ (%)	Average O_2 Conc.** (% c_p)	c_p (% c_v)	c_m (% c_v)	Comp. Rate of Oxygen Fixation	c_p (% c_v)	c_m (% c_v)	Comp. Rate of Oxygen Fixation	c_p (% c_v)	c_m (% c_v)	Comp. Rate of Oxygen Fixation	c_p (% c_v)	c_m (% c_v)	Comp. Rate of Oxygen Fixation	c_p (% c_v)	c_m (% c_v)	Comp. Rate of Oxygen Fixation	c_p (% c_v)	c_m (% c_v)	Comp. Rate of Oxygen Fixation
10	—	100	99.8	99.9	99.7	99.7	99.8	99.6	99.6	99.2	99.–	99.–	98.5	98.3	98.3	97.7	97.4	97.4	92.9	92.7	92.7
50	—	100	99.2	99.6	95.4	98.8	98.8	94.7	98.–	96.4	92.4	95.6	93.–	89.1	92.2	89.–	85.3	88.3	72.6	69.6	72.–
100	—	100	95.7	99.3	78.1	95.–	97.8	77.–	93.6	93.2	73.3	89.2	87.3	68.7	83.5	81.3	64.–	77.8	57.8	45.5	55.3
200	—	100	84.9	98.8	24.2	83.9	96.1	23.5	81.6	88.5	21.7	75.1	79.4	19.5	67.4	71.–	17.4	60.3	43.6	10.7	37.–
300	90	97.3	71.4	98.4	—	68.4	95.1	—	66.1	86.–	—	59.7	75.4	—	52.4	66.–	—	45.9	38.–	—	27.1
400	200	87.5	65.–	98.3	—	55.9	94.9	—	54.–	85.4	—	48.6	74.4	—	42.3	64.9	—	36.9	36.8	—	20.9
500	310	76.2	61.–	98.2	—	45.6	94.6	—	44.–	84.7	—	39.4	73.5	—	34.2	63.7	—	29.6	35.6	—	16.5
1,000	820	44.9	54.4	98.1	—	24.–	94.3	—	23.–	84.–	—	20.5	72.4	—	17.7	62.4	—	15.2	34.4	—	8.4
2,000	1,820	24.6	52.2	98.1	—	12.6	94.3	—	12.1	84.–	—	10.8	72.4	—	9.3	62.4	—	8.–	34.4	—	4.4

* Strong turbulence.
† Very slight turbulence.
‡ Where oxygen concentration = 0.
** In volume where oxygen concentration greater than 0.

higher concentration of oxygen in the water/floc interfacial surface will be maintained, as a result of which the supply of oxygen to the floc will remain high.

Experiments carried out in a treatment plant with activated sludge at very high rates of oxygenation and with high turbulence in the aeration tank will be reported in a subsequent part of this series.

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DISCUSSION

BY A. M. BUSWELL

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The theoretical analysis of oxygen uptake by water from air, as given by Mr. Pasveer (1), is most interesting. It is felt, however, that some confusion may arise due to the author's use of the word "diffusion" as applying to the process occurring at the air-water interface, as well as to the migration of the solute in the liquid phase. American literature and chemical dictionaries limit the term "diffusion" to the process occurring within a phase (gas, liquid, or solid). The first process, saturation of the interface, is almost instantaneous, as pointed out by the author and several earlier workers (2); the second process is very slow (3)(4).

It is further of interest to compare the author's third conclusion, ". . . that the energy employed for aeration should be directed towards the creation of a new water-air interfacial surface," with that of Buswell (5)(6): "The Importance of Stirring. . . . The air must saturate the liquor or water immediately below the surface of contact. Langmuir has shown that enough molecules strike such a surface to saturate it in an infinitesimally short time, giving a thin layer of water saturated with oxygen immediately in contact with the air surface. . . . Stirring will sweep away the saturated film from the air surface and bring it down in contact with the activated sludge particles."

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REDUCTION OF EXCESS SEWAGE FLOWS AT MILWAUKEE *

By Raymond D. Leary

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The Milwaukee Metropolitan Sewerage District embraces some 96,200 acres of land, of which the total sewered area is approximately 65,000 acres. The total population of the District is 855,000; population tributary to the sewered area is 815,500, or 96.5 per cent of the total. The 155 mi. of main intercepting sewers under the direct control of the Commission serve an area that contributed a sewage flow averaging 163.4 m.g.d. in 1952, with peak flows of 232 m.g.d.

The general subsoil in the district is made up of two general classifications, the north half having a clay mixture and the south half being made up of a wet sandy material.

During periods of excessive rainfall or melting snow, certain parts of the intercepting sewer system are subject to serious surcharging. Many basements experience flooding and considerable surface flooding occurs. As a result, much blame for the condition is charged to the intercepting sewers.

Although the intercepting sewers are not designed to carry storm water, except for a nominal amount of infiltration, storm water is transferred to them where connections are made to the sewers carrying combined storm water and sanitary flow, and from basement drains and streets flooded with storm water.

To function satisfactorily, each of the sewer systems in a separately sewered district should perform its work without interference from the other. Unfortunately, 100 per cent satisfaction is rarely achieved. Usually the storm sewers are unable to carry away the storm runoff rapidly enough and some surface water finds its way into the sanitary sewers. The sanitary sewers, designed to carry the relatively smaller sanitary flow, are unable to carry storm flow and become surcharged, flowing under pressure. The water level in the manholes may rise well above the floor level of adjacent basements, causing flooding and concomitant complaints.

Storm water finds its way into the sanitary sewers in one, or more, or all of the following methods:

1. Infiltration.
2. Foundation drains.
3. Roof downspouts.
4. Surface water entering cover of depressed manholes.
5. Cross-connections.
6. Inadequate drainage basin capacity.

Each of these is discussed hereinafter in a general manner.

Infiltration

A sanitary sewer constructed in soil containing ground water receives some of the ground water because of leaks in sewer joints and manhole walls.

In early construction, sewer joints were made tight by jute and cement grout. The success of this procedure depended entirely on the care exercised in packing the grout in the tile

* Presented at 1953 Annual Meeting, Central States Sewage and Industrial Wastes Assn.; Peoria, Ill.; June 3–5, 1953.

bell. The results were not always the best at the bottom of the pipe, especially in a wet trench. Later a preformed asphaltic strip caulked into the bell was used, to overcome the objections of the cement grout. In some cases the asphaltic strip would shrink with age, opening up the joints. The present construction of sewer joints, using a hot-poured asphaltic material or a patented process that forces cement grout into the bell, is believed to reduce infiltration into sanitary sewers to a minimum. The infiltration through the walls of manholes can be held to a minimum by using a monolithic concrete manhole shaft or, if brick manholes are desired, to plaster the outside of the shaft with a cement mortar.

It is virtually impossible to construct a completely tight sanitary or intercepting sewer in a separate system. The design of the sewers, therefore, should include an allowance for infiltration. At Milwaukee the infiltration allowance in sewer design has been 820 g.p.d. per acre. This value was selected because infiltration determinations made in Illinois cities showed the average infiltration to be approximately 800 g.p.d. per acre. Sewer gagings on some of Milwaukee's main sewers indicate an infiltration rate of considerably less than 820 g.p.d. per acre.

The Milwaukee Metropolitan Sewerage Commission in its endeavor to relieve the surcharging of sanitary sewers and flooding of basements caused by excessive storm waters has jointly sponsored a program to have the various governmental units in the drainage district adopt a uniform ordinance prohibiting foundation drains, down spouts, and other illegal waters from entering the sanitary sewer system under all future construction programs. These provisions are set forth in a set of general standards set up by the cooperating bodies and generally in accordance with "Tentative Standards for Sewage Works" as prepared by the Committee on Development of Uniform Standards for Sewage Works for the Upper Mississippi and Great Lakes Boards of Public Health Engineers.

Foundation Drains

It has been the custom to permit the connection of foundation drains to sanitary sewers. These drains consist of 4-in. or 6-in. tile at the base of the foundation wall, laid with open joints and connected to the sanitary sewer.

The amount of water contributed to the sewers by this practice is appreciable. An average house will have between 100 and 150 ft. of open joint tile. In a sandy soil each house may contribute as much as 0.001 cu. ft. per second; at 5 homes per acre this amounts to 0.005 cu. ft. per second per acre. This is equivalent to the original design allowance for Milwaukee sewers; in other words, foundation drains in sandy soil double the sanitary flow as established in early designs. In clay soils the rate of flow out of the ground would be less, but of a longer duration. However, clay soil shrinks in dry periods and pulls away from house foundations. Where house downspouts discharge above ground close to the building, a heavy rain after a dry spell readily gets into the foundation drain, and possibly causes a greater rate of flow than that for sandy soils.

Roof Downspouts

Connection of downspouts to sanitary sewers is prohibited in Milwaukee. This prohibition is strictly enforced, as the runoff from five or six average size homes equals the capacity of an 8-in. sanitary sewer. An 8-in. sanitary sewer flowing full requires a slope of 4 ft. per 1,000 ft. If roof water from five or six homes were added to such a sewer, the water surface slope would be 16 ft. per 1,000 ft., which would mean the heading up

of water at and above the ground at the offending homes, resulting in flooded basements.

Surface Water Entering Manhole Tops

Sanitary sewer manhole covers located in certain areas, which are either not provided with storm sewers or where the storm sewers are inadequate, become submerged with surface water and the water flows into the manhole through the perforations in the cover. This is a source of surface water in sanitary sewers which is rarely understood to be objectionable.

Manhole covers sometimes have two pick holes, or one pick hole and four ¼-in. or 1-in. round vent holes. If these manholes become submerged as much as 6 in. the water entering the cover will be as much as 0.25 c.f.s. Three manhole covers thus submerged will admit enough water to equal the capacity of an 8-in. sanitary sewer, which in turn, as previously stated, requires four times the fall to carry the doubled flow.

The amount of damage caused by leakage through seemingly insignificant openings in the manhole covers actually proves to be enormous. All sanitary sewer manhole covers subject to surface flooding should be sealed watertight, with vents provided where necessary.

In connection with leakage into manhole covers, attention is called to the improper practice of residents, in areas not served by storm sewer, of opening manhole covers or knocking a hole in side of a manhole under the cast-iron frame to hasten drainage from the street surface into a sanitary sewer. Because of the larger opening this permits a much larger inflow than previously indicated, with a corresponding increase in basement flooding.

Cross-Connections

There are many possibilities of cross-connections whereby surface water gets into sanitary sewers. An obvious example is the home owner who illegally connects his downspouts to the sanitary sewer instead of constructing a longer tile line to the street curb or to a storm sewer. Installation of street inlets to relieve ponding, and connection of the inlets to the nearest manhole, which is possibly a sanitary sewer manhole, represents another source of storm water.

Interceptor overflows into storm sewers and creeks will backflow into the intercepter when the storm sewer or the creek is surcharged by excessive rains. Most of these installations have backwater gates, but even these sometimes fail due to a stick or stone preventing the gate from closing.

Reduction of Storm Flow in Sanitary Sewers

For a satisfactory separate sewer system the following general considerations are suggested:

It will be impossible to eliminate ground-water infiltration or existing foundation drainage except to the extent that the flow may be reduced by improvements to storm sewers and natural creeks so as to hasten the removal of surface water. The prohibition of future foundation drains should improve conditions in the new areas and reduce the load on the present intercepters over what it would have been if these restrictions were not placed in effect.

In low and rolling areas where depressions in grade cause flooding of sanitary manholes, liberal sized storm drains should be constructed to remove surface water quickly. Natural creeks and rivers which are inadequate in carrying capacity flood over their banks and cause backwater in the storm sewers, flooding street surfaces and intercepter spilling connections. The natural streams should be improved by deepening, straightening, and paving when necessary to reduce

flood heights and thus prevent surface water entering sanitary sewers.

Relief of Intercepting Sewers

To relieve the intercepting sewers of excessive flow, gravity overflows to the rivers and creeks, and to storm sewers, have been provided, as well as pumping facilities. The flow, which is diverted to the rivers and creeks, consists of mixed storm drainage and sanitary sewage. It is undesirable to use the creeks to transport this type of flow, but on the other hand it is for only a short period of time and it is not practicable to provide intercepting sewers and sewage treatment plant facilities adequate in capacity for such a large volume of flow occurring at relatively infrequent intervals. Also, of course, it is preferable to pump the flow to the creeks rather than to permit it to back up into basements.

In the design of creek improvements or storm sewers, no consideration need be given, in general, to interceptor overflow capacity or the amount of pumping station relief discharge. The design flow for the creek or storm sewer is based on the tributary area. Therefore, it automatically includes that portion of the storm flow which may be transported temporarily in an intercepting sewer and later diverted to a storm sewer or creek.

It would be preferable, however, if the amount of the mixed flow to be intercepted could be reduced under these circumstances, so that the intercepting sewer would not be called upon to handle such quantities as would cause surcharging. In other words, it would be preferable in the first place not to accept excessive flows due to storm water, rather than attempt to handle them and then have to provide means for disposing of such flows. Either method would make very little difference with respect to discharging sewage into the watercourses, but there would be much less basement flooding if no excess flows ever reach the interceptors.

The excessive flow in the intercepting sewers can be relieved by the following methods:

1. Elimination of any cross-connections between sanitary sewers and storm sewers, unless backwater valves or other devices are employed to keep storm water out of the sanitary sewers.
2. Gravity overflow to streams or storm sewers.
3. Pumping stations to remove excessive storm flows to streams or storm sewers.
4. Refusal of excessive flow at interceptor connections.
5. Additional intercepting sewer capacity in special cases.
6. Elimination of illegal connections to sanitary sewers or interceptors.
7. Improvement of drainage basin capacity.

In general, gravity overflows provide the simplest and best method of relief, aside from removing any cross-connections. The success of this method depends, however, upon the availability of a stream or large storm sewer at the proper elevation.

More liberal use of pumping stations probably is required in order to dispose of the excess flow reaching some of the intercepting sewers. This method of relief is costly, both to construct and to operate, but in some cases it appears to be the only practicable solution.

In the case of combined sewers where intercepting devices have been used, it should be possible to so adjust the intercepting device that under conditions of excessive flow it would close completely. An alternate method would be to build a vault and install an electrically controlled sluice gate therein, which would accomplish the same purpose. Thus, flow which could not be accommodated in the intercepting sewer would not be accepted.

The fact should be emphasized, however, that except in special cases it is not practicable to prevent basement flooding and surface ponding by means of additional sanitary intercepting sewers. Sanitary interceptors are primarily designed to conduct all sanitary sewage to a treatment plant or other outlet at whatever maximum rate of dry-weather sanitary flow occurs, plus a nominal allowance for unavoidable ground-water infiltration. If possible, no surface water or storm flow should be permitted to reach the interceptor. There are a number of basic reasons underlying the foregoing design criterion for intercepting sewers. Chief among these are: (a) It is totally impracticable from a cost point of view to provide intercepting sewers of such capacity that storm flow could be adequately accommodated, because it would mean duplicating at a low elevation the capacity of the creeks and all the storm sewers at a tremendous cost; and (b) unless a separate sanitary interceptor were also provided, such a huge sewer under Milwaukee conditions would provide several days' storage for the sanitary flow during dry-weather periods, and the sewer would then become virtually a huge septic tank with attendant obnoxious odors and much nuisance.

If basement and surface flooding are to be prevented, adequate storm sewers and creek channel capacity are required. It is also necessary to preserve interceptor capacity for the sanitary sewage and not utilize it for storm flow. If too much mixed storm water and sanitary sewage is taken into the interceptor at a connection with a so-called combined sewer, then interceptor capacity will not be available where strictly sanitary sewers are intercepted, with the result that basement flooding might result indirectly because of storm flows.

The ultimate cure for flooding lies in providing adequate storm-water facilities and not in increased interceptor capacity. This has been recognized as one of the important phases of clear water elimination in the Milwaukee area. In fact, it has been forcibly brought home by the rainfall record in the area, especially during the past two years, when on several occasions runoff was of flood intensity. This caused some of the main drainage basins to overflow the adjacent area, flooded streets in low sections, and finally flooded the basements of an estimated 10,000 homes in various parts of the drainage district.

The fringe area development in the district has been phenomenal. This, coupled with inadequate storm drainage basin capacity, has created a complex problem of lack of continuity of responsible authority to deal with drainage problems, as the rivers and drainage creeks do not respect municipal boundary lines. Therefore, the improvement of watercourses becomes a metropolitan function.

Discussion of the various phases of creek and river improvement work as part of the over-all program to help reduce the entrance of clear waters into the sanitary sewer system brought out the fact that there was no agency in the drainage district having legal authority to carry out such a project on a metropolitan basis, with the exception of the Milwaukee Sewerage Commission and the Metropolitan Sewerage Commission of the County of Milwaukee, which Commissions are authorized by state laws to "improve watercourses, including the building of storm sewers, needed for this purpose in order to prevent the surcharging of the sanitary sewer system."

Therefore, on September 9, 1952, both Commissions agreed to assume the responsibility of deepening, widening, and improving water drainage courses to reduce the surface flooding of many areas as part of the program to eliminate storm water from the sanitary sewer system and help to prevent the surcharging of the sewer system.

On September 15, 1952, both Commissions approved the work of deepening, widening, and improving about 6 mi. of Lincoln Creek, one of the main east and west drainage basins in the district. It had flooded during the past summer, causing considerable property damage.

Shortly after it was decided that both Commissions were to take over the project of improving Lincoln Creek, a survey locating the creek was made. A study of actual conditions in the field prompted the decision to remove all deposits of silt, debris, trees, shrubs, etc., from bank to bank at an average width of 30 ft. from the discharge of the creek into the Milwaukee River upstream to about its headwater source, a distance of some 6 mi.

Since time was of the essence, due to the necessity for completing the work while the weather was still favorable, informal bids based on hourly rates for both equipment and labor were obtained from about 10 local contractors. The contractor submitting the lowest informal bid was contacted immediately and on October 8, 1952, work was started on clearing brush, debris, etc., from the slopes and bottom of the creek, removing silt deposits and straightening sharp bends. The work was completed on November 15, 1952.

The work was able to progress rapidly as no rights-of-way were necessary: either the Milwaukee Park Commission or the suburban units of government held egress permission. This eliminated the time consuming work of acquiring rights-of-way from abutting property owners.

It is interesting to note that in deepening the channel many storm sewer outlets were uncovered, which indicated that only about 10 to 40 per cent of the free outlet was available and that in many instances the storm sewers were partially blocked off some distance from the outlet by silt deposits.

Each respective unit of government responsible for maintenance of these storm sewers was immediately notified to clean out the silt deposits, which was done as the channel improvement work progressed.

Shortly after the completion of the Lincoln Creek improvement project, a heavy and prolonged rain fell in this general drainage area. Such an intensity had previously caused serious basement flooding and property damage; but with the added unrestricted capacity of the improved channel, the storm runoff was confined to the improved section with no flooding of the area.

This channel improvement work was considered to be an emergency job, as the particular drainage area had been subject to serious flooding during the past several years. However, both the City and Metropolitan Commissions have jointly worked out a master plan for improving all of the drainage channels in the metropolitan drainage district, which includes a complete study and survey of the main drainage channels and all of the tributaries, complete engineering outline plans for the temporary and ultimate channel development, estimated cost of construction work and land acquisition, as well as coordinating all work with local and county planning commissions to establish a definite route for the entire length of each drainage course to obtain the greatest land use of adjacent territory.

Pending the construction of adequate storm sewers and the improvement of watercourses, it is possible to provide some temporary relief when the intercepting sewer is surcharged by storm flow by the construction of additional overflows and pumping stations. These devices would relieve the intercepting sewer and restore some of its capacity for sanitary sewage, for which it was designed. Thus, relief would be provided for basement flooding, which results from interceptor surcharging and

the resultant backing up into the sanitary sewers. Relief of the major flooded areas will be dependent upon the construction of additional storm sewers and creek channel improvements. Surface or basement flooding which occurs in connection with storm sewers or combined storm and sanitary sewers can be relieved by additional storm sewer capacity, but not by additional interceptor capacity.

The conditions surrounding each location where surcharging occurs are special to each particular location. To determine the best solution for relieving surcharging in the intercepting sewers, therefore, it is necessary to make a detailed examination of the various factors involved in each case. It should be remembered, however, that the ultimate permanent solution of the problem lies in providing adequate surface drainage and in excluding storm water from the sanitary sewers and interceptors. Immediate temporary relief can be secured in many locations, however, and the present conditions much improved.

Treatment Plant Loading Data

Sewage treatment at the Milwuakee plant is accomplished by the conventional activated sludge method. This method was selected because it afforded a high degree of treatment, which was felt necessary in order to amply protect the water supply and bathing beaches and to maintain conditions in adjacent waters suitable for recreation purposes.

With the necessity for a high treatment standard in mind, the Sewerage Commission established a minimum standard of 90 per cent for removal of suspended solids and B.O.D.

Actually the over-all picture has been somewhat better than the established standard. Twenty-eight years of continuous operation show 92 to 95 per cent suspended solids removed and 93 to 96 per cent B.O.D. removals.

The Metropolitan District, or drainage area served by the sewage treatment plant, is approximately 152 sq. mi. in area (within Milwaukee County) and has a total population of 855,000 with a connected population of approximately 815,500.

Milwaukee and the surrounding area is a highly industrialized community with extremely diversified industry. Many of the industries contribute large volumes of highly concentrated wastes. The largest contributions and by far the most concentrated wastes, from the standpoint of plant loading, emanate from the brewing, malting, tanning, and meat packing industries.

The sewage treatment plant serves a population of 815,000 people. Assuming 0.17 lb. of 5-day B.O.D. per capita per day for domestic waste only, the population equivalent of the sewage and industrial wastes received at the plant during the 10-year period from 1942 to 1951, inclusive, is in excess of 2,000,000. This high population equivalent is the result of the large volume and high concentration of industrial wastes.

The present sewage treatment plant was constructed in three stages. The original 85-m.g.d. unit was built in the early 1920's and placed in operation in June, 1925. Late in 1935 the plant capacity was increased by 69 m.g.d., making a total of 154 m.g.d. Again late in 1951 additional capacity was added, bringing the total to 200 m.g.d.

The original 85-m.g.d. unit was of the ridge-and-furrow type as related to distribution of air. Additional capacity supplied has been of the spiral-flow type.

The original treatment plant was designed to treat 85 m.g.d. of sewage containing 250 p.p.m. of suspended solids and an approximately like amount (256 p.p.m.) of B.O.D., with a 6-hr. average detention and 1.5 cu. ft. of air per gallon of sewage treated.

The mixed liquor solids were to be maintained at 2,500 to 3,000 p.p.m. Later additions were designed to function on the same basis as the original design.

Sewage received at the plant has gradually increased in strength over the years. The 10-year averages (1942 through 1951) with a 154-m.g.d. plant capacity were as follows: Sewage treated 130.43 m.g.d.; suspended solids 306.3 p.p.m. (289 p.p.m. minimum, 325 p.p.m. maximum); and 5-day B.O.D. 328.8 p.p.m. (296 p.p.m. minimum, 366 p.p.m. maximum).

The average sewage volume treated during this period is considerably below the treatment plant capacity. The averages for suspended solids and 5-day B.O.D., however, are substantially above the basic design loading—22.5 per cent for suspended solids and 26.5 per cent for B.O.D. This increased loading obviously influences treatment capacity afforded on the volumetric basis.

Calculating and projecting the sewage flows for the 10-year period, using the original basic design figures for sewage concentration, equivalent flows are obtained which are highly enlightening regarding previously established volumetric capacities. These equivalent sewage flows are as follows:

Susp. solids basis	159.72 m.g.d.
B.O.D. basis	163.15 m.g.d.

Obviously, the calculated equivalent sewage flows are in excess of designed capacity.

In 1952 the plant capacity was increased from 154 to 200 m.g.d. Data covering the year 1952 are as follows:

Sewage flow, av.	163.4	m.g.d.
Sewage flow, max.	232	m.g.d.
Susp. sol., av.	289	p.p.m.
B.O.D.	295.5	p.p.m.
Air used, per gal. treated	1.39	cu.ft.

Calculating and projecting the equivalent sewage flow for 1952 on the basis of suspended solids and B.O.D. again results in significant flow increases. The increased sewage flows are perhaps totally or partially compensated for by increased detention afforded. The equivalent flows calculated on the basis of suspended solids and B.O.D. are 188.9 and 188.6 m.g.d., respectively.

It is apparent that should sewage concentrations remain at their present levels as to suspended solids, and more particularly B.O.D., when total volumetric treatment capacity is reached the plant will be considerably overloaded. Also it should be noted that the foregoing calculations are based on gross treatment capacity. No accounting has been made for aeration tank outage (cleaning, repairs, etc.) or for loss of capacity in the old plant due to the reduced size of the south aeration tanks in the west plant. Tank outage represents approximately 2.5 per cent (5 m.g.) of the total tank capacity. Similarly, capacity reduction of the West Plant represents 2.8 per cent (2.4 m.g.) of the total tank capacity, making the total loss in treatment capacity approximately 7.4 m.g.

SEWER PIPE ROUGHNESS COEFFICIENTS *

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Probably the most commonly used formula for flow in sewers is the Manning formula,

$$V = \frac{1.486}{n} r^{2/3} s^{1/2}.$$

This formula works equally well for closed pipes or open channel flow, both flow conditions occurring in sewers.

When new pipe materials are developed or manufacturing methods utilizing traditional pipe materials improve the internal surfaces of pipes, it is necessary to evaluate the hydraulic roughness coefficient, n, as used in the Manning formula, if the best possible job is to be done in the design of sewers. During the summer of 1952 the author ran a series of experiments, using two common sewer pipe materials, in an effort to evaluate n. The two pipe materials used were vitrified clay and asbestos cement.

Description of Apparatus

Vitrified clay sewer pipe used in the study was Standard Strength (ASTM Designation C13–50T), in 3-ft. lengths, using jute and cement mortar joints. The asbestos cement sewer pipe used was Class 1, in 13-ft. lengths, with the Ring-Tite joint. Both shipments of pipe were from regular stock, with no irregular pipe being used on the test job.

For the test runs, 300 ft. of pipe line was constructed on an adjustable trestlework formed of 2 x 6 planking, supported by bents at 4-ft. intervals, which in turn supported cradles placed under each vitrified clay pipe and at intervals of about 4 or 5 ft. under the asbestos cement pipe. The pipe lines were laid on the cradle about 4 ft. above ground surface.

Water was pumped from the adjacent river into a 1,000-gal. tank at the upper end of the pipe line by a 1,500-g.p.m. gasoline-motor-driven centrifugal drainage pump. This wooden tank contained a stilling baffle to cut down turbulence and was equipped with a sheetmetal adapter at the effluent end designed to develop pipe-line velocity as soon as possible, with small entry loss of head. At the discharge end of the 300-ft. pipe line another 1,000-gal. tank was located in such a position that flow from the pipe being tested had a free fall into this tank. A baffle in this tank stilled the flow; the tank discharge was carried through a 90° V-notch, sharp-crested weir into a plank flume for return to the river.

At intervals of 25 ft. along the pipe line 6-in. wyes were placed at an angle of 45° with the horizontal to reproduce quite accurately actual sewer construction conditions. Adjacent wyes were on alternate sides of the pipe line. In the clay pipe line the 6-in. wyes were cast integral with 3-ft. lengths of 8-in. sewer pipe. On the asbestos cement pipe, however, 6-in. cast-iron adapters or wyes were attached by cutting holes in the main pipe line in accordance with instructions of the manufacturers of the asbestos cement pipe. These 6-in. wyes were plugged with clay pipe stoppers and cement

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mortar so no water was lost through the branch connections.

Hook gages designed to measure to the nearest 0.001 ft. were used to measure the water surface elevation at seven points along the pipe line and to measure the head on the effluent weir of the discharge tank. The seven gaging stations were located with three near the upper end, three near the lower end, and one in the middle of the pipe length. The pipe line was drilled near the bottom at each point, and a $\frac{5}{8}$-in. hose was connected to transmit water surface in the pipe line to a stilling well outside. The hook gages were located in these stilling wells (Figure 1).

An electrical conductance apparatus was used to determine the time of passage of a brine slug between two check points. This gave a physical measurement of velocity, which was a rough check of the velocity as measured by the Q/A method and served as a means of checking possible field blunders.

The 90° V-notch weir was calibrated in the field, and a rating curve and discharge formula were developed relating head on the weir and discharge.

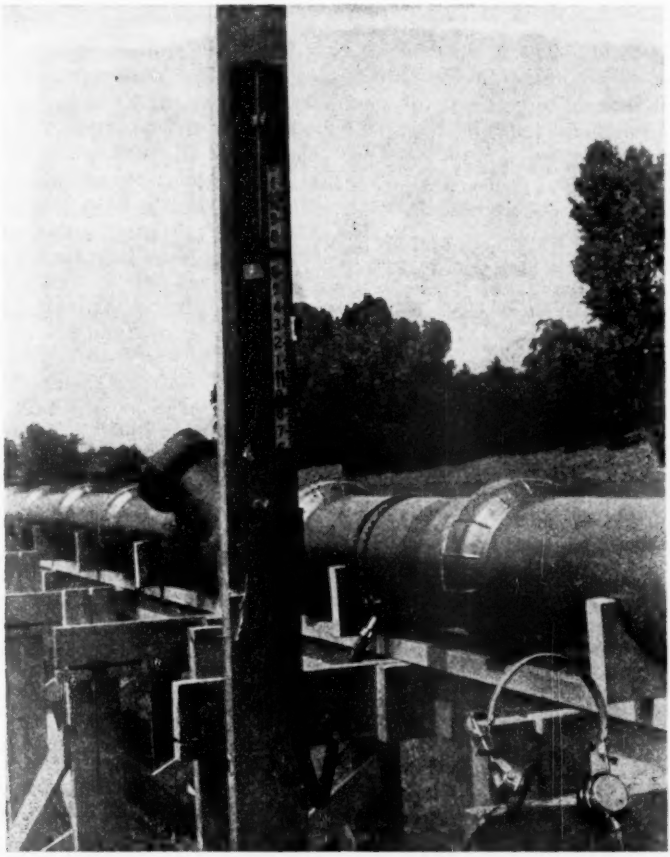

FIGURE 1.—Typical hook gage station and wye installation. Water surface profile is gaged from small stilling basin connected to pipe tap by hose.

Internal pipe diameters were measured for both pipe lines, and it was found that the clay pipe diameter varied less than 1/16 in. from 8 in., whereas the asbestos cement pipe was within 1/16 in. of 7 13/16 in. All calculations involving the pipe diameter were based on clay pipe at 0.667 ft. diameter and asbestos cement pipe at 0.651 ft. diameter.

Pump discharge was controlled by means of a 4-in. gate valve on the pump discharge. It was found that discharge, after being set at a fixed amount, remained constant within any time limits used in the investigation. This system gave a uniform discharge, of any desired rate, for the duration of any test run. The upper tank was designed so the pipe line could be forced to run at any depth of flow from approximately 1 in. deep to a condition of flowing under pressure at the upper end. A timber was placed across the lower end of the pipe line to force the pipe line to flow under pressure throughout its entire length for a few runs. Most of the investigation was devoted to the pipe line flowing as an open channel with free discharge at the lower end.

TABLE I.—Location of Fittings on Pipe Lines at 0.25 and 0.40 Per Cent Grades

8-In. Vit. Clay Pipe		8-In. Asb. Cement Pipe	
Station	Fitting	Station	Fitting
0+00	Outlet tank	0+00	Outlet tank
0+14	Electrodes	0+14.0	Electrodes
0+20	Hook gage	0+18.5	Hook gage
0+24	Wye, L	0+38.5	Wye, L
0+48	Wye, R	0+51.2	Hook gage
0+50	Hook gage	0+65	Wye, R
0+72	Wye, L	0+82.1	Hook gage
0+80	Hook gage	0+90.6	Wye, L
0+96	Wye, R	1+16.2	Wye, R
1+23	Wye, L	1+42.3	Wye, L
1+47	Wye, R	1+47.0	Hook gage
1+48.8	Hook gage	1+68.0	Wye, R
1+71	Wye, L	1+94	Wye, L
1+98	Wye, R	2+19.7	Wye, R
2+20.8	Hook gage	2+21.4	Hook gage
2+25	Wye, L	2+45	Wye, L
2+49	Wye, R	2+51	Hook gage
2+50.8	Hook gage	2+71.4	Wye, R
2+73	Wye, L	2+83.2	Hook gage
2+80.8	Hook gage	2+85.0	Brine inlet
2+85	Brine inlet	3+00	Inlet tank
2+97	Wye, R		
3+00	Inlet tank		

Method of Conducting Test

Each pipe line was carefully laid to alignment and grade at every 25-ft. station, the grade being adjusted until it was within a very few thousandths of a foot (usually less than 0.006 ft.) of a perfect grade. As soon as each series of runs on one pipe line was completed, levels were again run to ascertain that no movement had taken place.

The two grades selected for each pipe material were 0.25 per cent and 0.40 per cent, and a series of runs was completed at each grade. Pump discharge was adjusted so that there were at least eight runs on each pipe line at depths varying from 1 in. to flowing full under pressure. Each run was repeated as a check on the fieldwork.

As soon as one depth of flow had been established, after irregular surges caused by changing the pump discharge had passed through the pipe and tanks, individual hook gage readings were taken at each of the seven gaging stations and at the two hook gages located in the discharge tank. Velocity was immediately checked by the electrical apparatus; water temperature was recorded for each run.

Table I gives the location of wyes, hook gage stations, and salt solution electrode and inlet points on both pipe lines at both slopes. Table II gives actual field dimensions and levels of the four test conditions. Tables III and IV give the depth of flow in the pipe, or the distance from pipe invert to the free water surface, for each test run. Simultaneous values for head on the discharge weir, water temperature, and time of traverse of brine slug along 271 ft. of pipe also are tabulated.

TABLE II.—Pipe Dimensions and Elevations

Vitrified Clay Pipe				Asbestos Cement Pipe			
Station	Elev. Top of Pipe	d'* (ft.)	Elev. of Invert	Station	Elev. Top of Pipe	d'* (ft.)	Elev. of Invert
(*a*) Slope, 0.25 Per Cent							
0+00	106.521	—	—	0+00	106.485	—	—
0+20	106.572	0.729	105.843	0+18.5	106.535	0.701	105.834
0+50	106.647	0.727	105.920	0+51.2	106.617	0.698	105.919
0+80	106.726	0.729	105.997	0+82.1	106.693	0.698	105.995
1+48.8	106.905	0.732	106.173	1+47.0	106.861	0.695	106.166
2+20.8	107.076	0.724	106.352	2+21.4	107.047	0.708	106.339
2+50.8	107.148	0.732	106.416	2+51.0	107.118	0.703	106.415
2+81.0	107.247	0.732	106.515	2+83.2	107.203	0.708	106.495
3+00.0	107.280	—	—	3+00	107.238	—	—
(*b*) Slope, 0.40 Per Cent							
0+00	106.077	—	—	0+00	106.041	—	—
0+20	106.150	0.729	105.421	0+18.5	106.108	0.701	105.407
0+50	106.276	0.727	105.549	0+51.2	106.243	0.698	105.545
0+80	106.398	0.729	105.669	0+82.1	106.369	0.698	105.671
1+48.8	106.678	0.732	105.946	1+47.0	106.627	0.695	105.932
2+20.8	106.968	0.724	106.244	2+21.4	106.923	0.708	106.215
2+50.8	107.084	0.732	106.352	2+51.0	107.047	0.703	106.344
2+81.0	107.218	0.732	106.486	2+83.2	107.179	0.708	106.471
3+00	107.280	—	—	3+00	107.235	—	—

* Distance from top of pipe to invert, equal to diameter plus one wall thickness.

Results and Conclusions

Typical profiles of clay pipe line showing water surface slopes for each run are given in Figure 2. It was observed that irregularities in depth of flow occurred near the upper and lower ends of the pipe line. For this reason, the three middle gage readings, representing approximately 140 ft. of pipe between stations 0 + 80 and 2 + 20, were used to support the calculations for the roughness coefficient. Energy gradient profiles were computed and plotted at a distance of $V^2/2g$ above the water surface, and the slope of the energy gradient was used in the Manning formula.

The equation developed experimentally for the discharge weir was

$$Q = 2.47\ H^{2.45}$$

in which Q is discharge, in cubic feet per second, and H is head on the weir crest, in feet. This formula agrees closely with that of other recent experiments. From the curve of this equation were taken discharge values for head measurements made on each run; using this discharge and the cross-sectional area of channel, the mean velocity was computed by

$$V = Q/A.$$

Values of the hydraulic radius were computed as needed. With all the factors in the Manning formula now computed from experimental data, it was a simple matter to compute values of n for each pipe line, for several depths of flow and on two different slopes.

The variation of mean velocity, as measured by the Q/A method, with depth of flow, pipe material, and slope is shown clearly in Figure 3. It is to

be noted that for all slopes and materials the velocity was near or above 1.0 f.p.s. when depth of flow was above the 0.1-diameter ratio. At the 0.40 per cent slope, velocities in the clay pipe were greater than in the asbestos cement pipe until a 0.9-depth ratio was encountered. For the 0.25 per cent slope, velocities in the clay pipe exceeded velocities in the asbestos cement pipe until a 0.64-depth ratio was encountered. Above these two depth ratios, velocity in the asbestos cement pipe exceeded velocity in the clay pipe. It is also to be noted that velocities flowing half full and flowing full are not equal for either material and that comparisons of the two materials show a reversal of trends between these points. At 0.5-depth flow the clay pipe velocity is greater than the asbestos cement pipe velocity; at full depth the asbestos cement pipe velocity is greater.

The variation of pipe line discharge, for both materials and at both slopes, for all ratios of depth of flow, is given in Figure 4. It is to be noted that the 8-in. clay sewer pipe at 0.40 per cent slope discharged more water at all depths of flow than did the 8-in. as-

TABLE III.—Field Data for Test Runs on 8-In. Vitrified Clay Pipe

Run No.	Depth of Flow in Pipe (ft.)*							Head on Weir (ft.)	Water Temp. (° F.)	Salt Solution Time† (min.-sec.)
	0+20	0+50	0+80	1+48.8	2+20.8	2+50.8	2+81.0			
	(*a*) At 0.25 Per Cent Slope									
1	0.327	0.292	0.298	0.246	0.253	0.309	0.224	0.433	—	— —
2	0.384	0.370	0.367	0.329	0.313	0.379	0.280	0.505	—	— —
3	0.499	0.488	0.481	0.475	0.475	0.489	0.459	0.606	—	— —
4	0.180	0.150	0.156	0.113	0.121	0.159	0.105	0.250	—	— —
5	0.249	0.206	0.222	0.177	0.182	0.234	0.161	0.343	—	2 37
6	0.326	0.285	0.296	0.244	0.250	0.311	0.225	0.437	—	2 11
7	0.427	0.404	0.407	0.383	0.363	0.414	0.317	0.546	—	1 51
8	0.558	0.571	0.587	0.617	0.655	0.674	0.660	0.673	—	1 42
9	0.121	0.100	0.101	0.070	0.078	0.112	0.060	0.171	84.5	— —
10	0.235	0.197	0.209	0.168	0.169	0.219	0.148	0.323	88.5	2 40.7
11	0.329	0.290	0.297	0.241	0.251	0.307	0.227	0.433	90.5	2 08.1
12	0.417	0.391	0.390	0.368	0.338	0.395	0.309	0.528	90.	1 51.7
13	0.448	0.423	0.430	0.409	0.405	0.431	0.336	0.563	90.	1 48.9
14	0.512	0.507	0.505	0.496	0.498	0.516	0.478	0.619	90.	1 42.4
15	0.537	0.537	0.543	0.543	0.541	0.559	0.531	0.638	90.	1 41.7
16	0.556	0.570	0.576	0.625	0.646	0.664	0.650	0.663	88.	1 44.3
17	0.371	0.334	0.339	0.294	0.291	0.345	0.255	0.473	90.	2 00.3
	(*b*) At 0.40 Per Cent Slope									
18	0.131	0.182	0.154	0.113	0.107	0.137	0.096	0.253	88.	2 52.2
19	0.171	0.263	0.225	0.176	0.174	0.183	0.160	0.353	88.	2 11.0
20	0.251	0.356	0.316	0.260	0.253	0.263	0.233	0.461	87.	1 47.6
21	0.333	0.451	0.400	0.333	0.336	0.367	0.314	0.558	86.	1 33.7
22	0.527	0.559	0.517	0.470	0.434	0.490	0.406	0.663	77.5	1 25.3
23	0.571	0.603	0.579	0.556	0.494	0.559	0.515	0.702	77.	1 23.0
24	0.639	0.652	0.669	0.728	0.767	0.813	0.815	0.737	78.	1 21.2
25	0.635	0.647	0.668	0.722	0.754	0.798	0.807	0.739	78.	1 21.7
26	0.757	0.760	0.772	0.821	0.839	0.887	0.867	0.732	78.	1 23.0
27	0.072	0.095	0.075	0.051	0.049	0.073	0.047	0.126	78.	5 06.0

* Distance from pipe invert to hydraulic grade line.

† Mean time for brine slug to travel 271 ft. of pipe line.

TABLE IV.—Field Data for Test Runs on 8-In. Asbestos Cement Pipe

Run No.	Depth of Flow in Pipe (ft.)*							Head on Weir (ft.)	Water Temp. (° F.)	Salt Solution Time† (min.-sec.)
	0+18.5	0+51.2	0+82.1	1+47.0	2+21.4	2+51.0	2+83.2			
					(*a*) At 0.40 Per Cent Slope					
28	0.193	0.240	0.209	0.236	0.236	0.196	0.200	0.373	85.5	1 55.3
29	0.243	0.307	0.267	0.291	0.304	0.243	0.258	0.450	87.	1 40.3
30	0.299	0.376	0.328	0.346	0.395	0.296	0.318	0.524	87.3	1 31.3
31	0.347	0.442	0.385	0.387	0.458	0.347	0.375	0.580	88.	1 26.8
32	0.495	0.520	0.476	0.451	0.545	0.406	0.439	0.656	88.	1 21.8
33	0.561	0.571	0.564	0.540	0.626	0.574	0.569	0.706	90.	1 21.1
34	0.579	0.599	0.621	0.634	0.780	0.764	0.781	0.729	90.	1 20.0
35	0.782	0.777	0.802	0.794	0.957	0.961	0.960	0.729	90.	1 23.3
36	0.108	0.135	0.110	0.127	0.127	0.104	0.100	0.227	90.	2 48.4
					(*b*) At 0.25 Per Cent Slope					
37	0.128	0.104	0.113	0.135	0.122	0.085	0.092	0.213	86.	3 39.5
38	0.218	0.177	0.194	0.212	0.218	0.163	0.160	0.334	91.5	2 31.2
39	0.295	0.243	0.273	0.284	0.304	0.270	0.220	0.428	92.	2 07.5
40	0.346	0.287	0.324	0.329	0.359	0.325	0.262	0.487	92.	1 56.0
41	0.389	0.361	0.357	0.362	0.401	0.369	0.302	0.528	94.	1 50.0
42	0.448	0.437	0.425	0.418	0.468	0.435	0.436	0.583	93.5	1 49.3
43	0.392	0.360	0.358	0.360	0.401	0.378	0.299	0.530	94.	1 49.5
44	0.473	0.459	0.450	0.437	0.489	0.454	0.456	0.602	94.5	1 42.5
45	0.518	0.538	0.552	0.548	0.618	0.601	0.609	0.655	94.5	1 41.7
46	0.535	0.561	0.582	0.614	0.719	0.709	0.737	0.678	95.	1 37.4
47	0.571	0.614	0.647	0.703	0.864	0.853	0.922	0.701	95.	1 30.2
48	0.725	0.753	0.796	0.837	0.990	0.973	1.031	0.688	94.	1 31.4

* Distance from pipe invert to hydraulic grade line.
† Mean time for brine slug to travel 271 ft. of pipe line.

bestos cement at the same slope. At half full the clay pipe discharged 20 per cent more than the asbestos cement pipe. At the 0.25 per cent slope, discharge of both types of pipes was approximately the same, the clay pipe discharging more for depth ratios below 0.74 and the asbestos cement pipe discharging more at greater depth ratios.

The computed values of n are plotted against depth of flow in Figure 5. The plotted points for vitrified clay at 0.25 per cent indicate a straight-line variation with increasing values of n as the depth of flow increases. This tendency did not show with clay or asbestos cement pipe at the other slopes tested; therefore, arithmetic mean curves are drawn showing a comparison of the tests as performed. The values of n are all between 0.0075 and 0.011, with a tendency for n to increase as the slope increases. The slopes used in this investigation were both relatively flat. The curves drawn through the arithmetic mean value of n indicate that the vitrified clay sewer pipe was smoother than the asbestos cement pipe tested.

The values of n determined in this study are for new, clean, well-aligned pipe using river water of relatively low turbidity. Water temperatures throughout the study were high. From this limited study it is indicated that the correct value for the roughness coefficient to be used in design of sewers should be the same for new clay and new asbestos cement pipe. After sev-

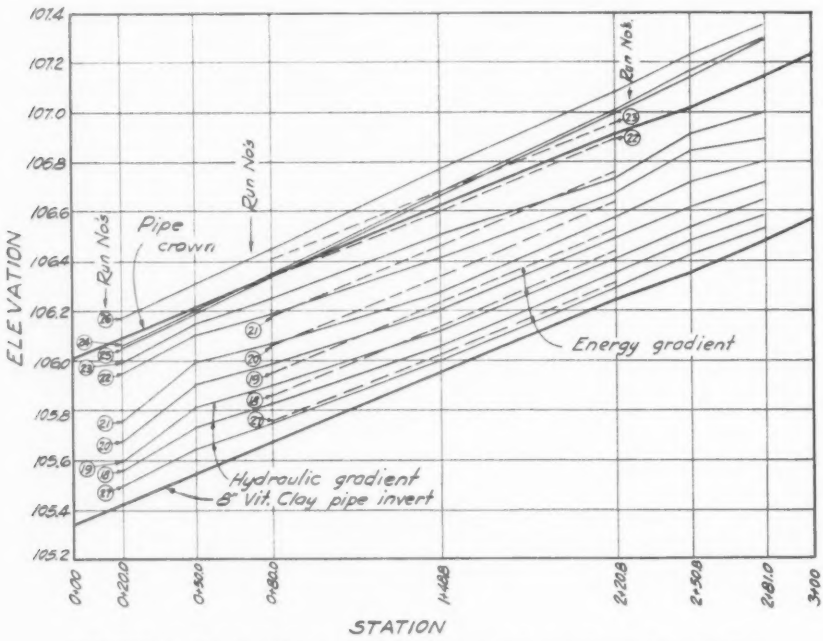

FIGURE 2.—Typical pipe, energy gradient, and hydraulic gradient profiles (see Table III for runs shown).

eral years of continuous use of pipe, the coefficient of roughness of the sewers no doubt will tend to be a coefficient which measures the effect of a slime- or grease-coated pipe line. Therefore, regardless of the structural pipe material,

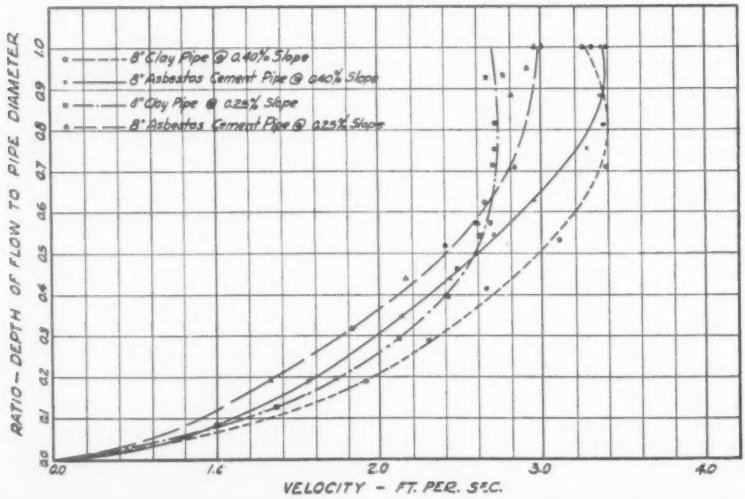
RATIO - DEPTH OF FLOW TO PIPE DIAMETER
VELOCITY - FT. PER. SEC.
8" Clay Pipe @ 0.40% Slope
8" Asbestos Cement Pipe @ 0.40% Slope
8" Clay Pipe @ 0.25% Slope
8" Asbestos Cement Pipe @ 0.25% Slope

FIGURE 3.—Effect of depth of flow on velocity as computed by A/Q method.

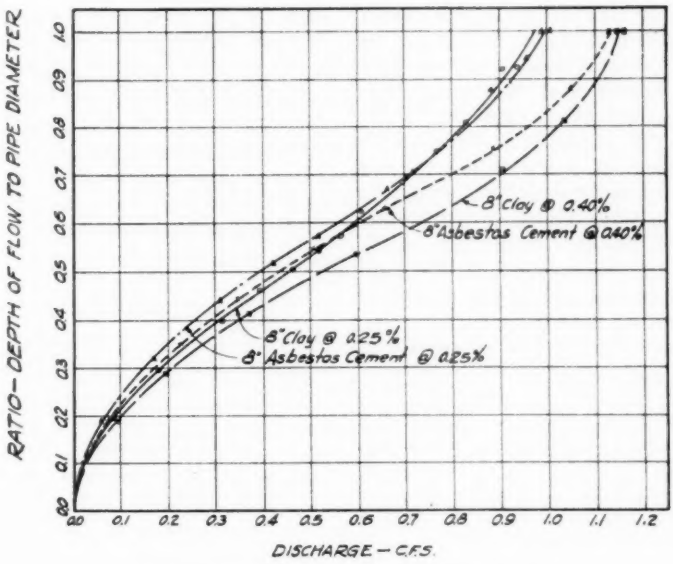

FIGURE 4.—Pipe discharge vs. depth of flow.

it would appear that the value of n would tend to be the same for any given slope, depth of flow, and pipe diameter. Present design practice suggests using different values of n for these two different sewer pipe materials, but this practice is probably questionable. Although this study

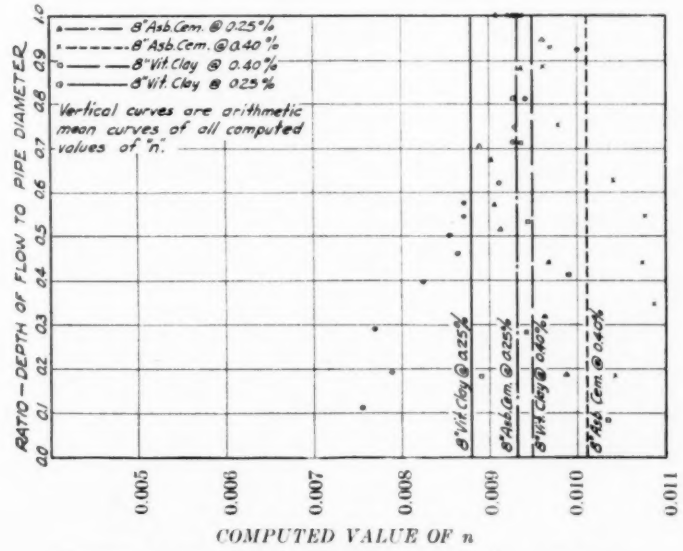
8" Asb. Cem. @ 0.25%
8" Asb. Cem. @ 0.40%
8" Vit. Clay @ 0.40%
8" Vit. Clay @ 0.25%
Vertical curves are arithmetic mean curves of all computed values of "n".
RATIO—DEPTH OF FLOW TO PIPE DIAMETER
COMPUTED VALUE OF n

FIGURE 5.—Mean value of Manning's roughness coefficient, n.

covers only 8-in. pipe and flat slopes, it indicates that the coefficient for design should be at least 0.012 or 0.013.

It is known that the value of n changes with depth of flow. This study suggests that n probably changes with slope; also that joints do not have as much effect on the roughness coefficient as some believe. Camp (1) states that "effective absolute roughness coefficients" are "relatively low and indicate that the joints in sewer pipe have little effect on the roughness."

More complete studies are needed in which a comparison is made between clay; asbestos cement; concrete, both plain and reinforced; corrugated metal; and perhaps cast-iron pipe. The pipe line should have a minimum length of 300 ft. to develop uniform flow for at least part of its length. Pipe diameters from 6-in. through 24-in. need to be tested at slopes varying from very gentle to quite steep. At the conclusion of this study, which might be sponsored jointly by the various manufacturers involved, engineers would be much better equipped to properly evaluate the Manning n, which is so important in sewer design.

Acknowledgment

The investigation reported herein was conducted as a project of the Ohio State University Research Foundation.

Reference

1. Camp, T. R., "Hydraulics of Sewers." *Pub. Works*, **83**, 6, 59 (1952).

NON-MEMBER MEETINGS OF INTEREST

The Third Annual Ohio Water Clinic Conference is to be held on the Ohio State University Campus, Columbus, Ohio, February 11–12, 1954. Details may be obtained from Professor K. W. Cosens, director.

Courses on the biology of sewage and stream sanitation, under the direction of Professors H. Liebmann and R. Demoll, will be held at the Bavarian Biological Experiment Station, Veterinärstr. 6, Munich 22, Germany. An introductory course is scheduled for March 8–12, 1954, with an advanced course during the period October 4–8, 1954. Closing date for reservations for the introductory course is February 15, 1954; for the advanced course, September 15, 1954. Further details are obtainable from Professor Liebmann at the address given.

The Third Southern Municipal and Industrial Waste Conference will be held at North Carolina State College, March 18–19, 1954. Details are available from Professor Nelson L. Nemerow, Department of Engineering, North Carolina State College, Raleigh, N. C.

The Fourth Inter-American Conference of Sanitary Engineering, organized by the Inter-American Association of Sanitary Engineering, will be held July 25–31, 1954, at São Paulo, Brazil. Detailed information may be secured by contacting the General Secretariat, Fourth Inter-American Conference of Sanitary Engineering, Postal Box 8099, São Paulo, Brazil.

Industrial Wastes

TRICKLING FILTER STUDIES ON FINE CHEMICAL PLANT WASTES *

By F. E. Reimers, U. S. Rinaca, and L. E. Poese

Process Research and Development Division and Factory Division, Merck & Co., Inc., Rahway, N. J.

As new processes are initiated in a fine chemical plant the problem of waste disposal becomes increasingly more difficult. To prevent pollution of nearby receiving streams, additional waste treatment facilities must be installed. More effort is placed on control of all process wastes at their source and some processes may require modifications to reduce the strengths and volumes of the wastes. If any of the new process wastes are toxic to aquatic life, have a high B.O.D., or cause an unpleasant taste or odor in the receiving stream, complete treatment or destruction is often necessary. Eventually the expanded plant contains a variety of waste treatment units, many of which lack flexibility, but all of which represent a considerable capital expenditure and have a high operating cost.

Such has been the experience at the Stonewall Plant of Merck & Co., Inc., located on the South Fork of the Shenandoah River at Elkton, Va. Manufacturing operations started on a small scale in 1941. All of the wastes were discharged directly into the river. As other processes were introduced, it became necessary to segregate and dispose of certain strong wastes by other means. As Stonewall plant operations were expanded with fermentation and synthetic medicinal manufacture (antibiotics, vitamins, and sulfa drugs), additional waste treatment facilities were provided. These facilities represent a considerable investment and operating costs have been extremely high.

Wastes and disposal methods at the plant fall into the following general classifications:

1. Strong waste liquors, having a B.O.D. in the range of 3,000 to 100,000 p.p.m., have been evaporated to a concentrate, which was incinerated. These wastes have included fermentation process spent liquors, fine chemical mother liquors, washes, concentrates, and still residues. Certain toxic wastes have been subjected to preliminary treatment at the source.

2. Weak liquid wastes, which comprise selected dilute liquors from various processes, are discharged directly to a common sewer emptying into an equalization basin. This basin effects a pH equalization and some B.O.D. reduction. Facilities have been provided for oil skimming and sludge removal. The effluent passes through a second (earthen) skimming basin prior to being discharged to the river.

3. Cooling waters and jet discharges of negligible B.O.D. enter the second basin from a separate sewer.

* Presented at 38th Annual Meeting, New Jersey Sewage and Industrial Wastes Assn.; Atlantic City, N. J.; Mar. 11–13, 1953; and at Seventh Annual Meeting, Virginia Industrial Wastes and Sewage Works Assn.; Richmond, Va.; May 21–22, 1953.

4. Sanitary wastes are treated in a Clarigestor unit followed by chlorination. The effluent is discharged to the second basin.

5. Solid wastes in the form of filter cakes and trash are incinerated. Ashes are deposited in a coverable dumping area.

Most of the waste treatment facilities are shown in Figure 1.

River Conditions

The Shenandoah River is a Class A stream, being used by many communities as a source of potable water and harboring several species of game fish, the smallmouthed bass being the most popular. Bass weighing from 2 to 6 lb. have been caught below the plant outfall. In 1951 a 17-in. rainbow trout was caught about 1 mi. downstream.

The Stonewall plant's B.O.D. load to the river has varied from 1,000 to 5,000 lb. per day. The waste is well distributed across the width of the river. Oxygen depletion of the river water has never been greater than 30 per cent during extremely low flow periods and then for only short periods of time. Generally, the dissolved oxygen for several miles below the plant is in the range of 90 to 105 per cent of saturation due to rapid aeration at several riffles.

River bottom surveys conducted by the company's waste disposal laboratory and the U. S. Fish and Wildlife Service have at times indicated lower bottom animal populations for several miles downstream than found above the plant outfall. It is known that aquatic growth, *Sphaerotilus*, creates an unfavorable environment for the larvae of mayflies, caddisflies, and other bottom animals that provide food for minnows and larger fish life. The slime growth, which apparently thrives on easily assimilated nutrients such as sugars and proteins, is regarded as a fairly effective B.O.D. remover.

The Stonewall waste disposal problem was thoroughly studied with the following objectives in view:

1. To improve the effluent to the river.

2. To decrease operating costs.

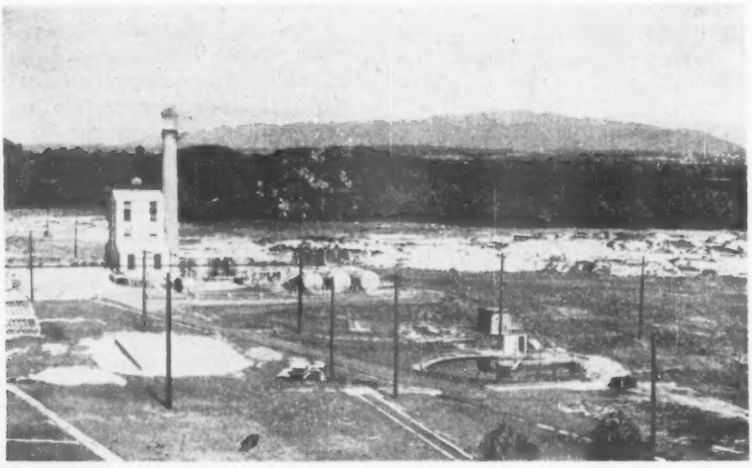

FIGURE 1.—Stonewall plant waste treatment units, including equalization basin (left foreground), Clarigestor (right foreground), and evaporation and incineration facilities (left center).

3. To eliminate the possibility of air pollution from incineration of wastes.

4. To devise a simplified scheme of waste treatment which would require considerably less supervision and would eliminate the complex system of wastes segregation and handling.

After a search of the literature and discussions with consultants, it was concluded that pilot-scale investigations of biological treatment methods should be conducted. Of the various types of treatment, biofiltration (1) (2) (3) appeared to offer the greatest possibilities.

Pilot-Plant Operations

Trickling Filter Construction

A pilot-scale trickling filter unit was installed in October, 1951, for the treatment of waste liquors from fermentation processes. The performance data of this unit were to serve as a guide for further studies.

The unit consisted of an 8-ft. diameter by 8-ft. depth wooden tub filled with graded and washed 2½-in. by 4-in. limestone to a depth of 6 ft. and supported by steel bar gratings. The filter was placed in the center of a shallow concrete basin which sloped to a sump. The feed distributor was constructed of a notched angle-iron arm rotated at 4 r.p.m.

Feed and settling tanks consisted of (a) an agitated tank for storing and neutralizing the fermentation wastes, (b) a tank for settling out solids in the neutralized feed, and (c) a tank for settling out sludge from the trickling filter effluent.

All feed and recycle streams were handled by means of proportioning and centrifugal pumps and flow rates were measured with rotameters.

Spent Broth Treatment

The filter was operated for five weeks at a recirculation ratio of 12 to 1 followed by four weeks at 18 to 1 recirculation. The results of this study are shown in Table I.

TABLE I.—Single-Stage Trickling Filter Treatment, Fermentation Waste Liquors

Item	At 12:1 Recirc.	At 18:1 Recirc.
Average feed B.O.D.* (p.p.m.)	3,500	4,100
Toxicity threshold (%)	—	0.08
pH	7.5 to 8.0	7.5 to 8.0
Feed rate (g.p.h.)	20	20
Loading (lb. B.O.D./cu. yd./day)	1.2	1.6
Recirculation rate (g.p.h.)	240	360
Effluent settling time (hr.)	1	0.7
Average effluent B.O.D. (p.p.m.)	1,175	890
B.O.D. reduction (%)	66	78
Effluent pH	7.9	7.9
Sludge produced (gal./1,000 gal. feed)	3	4.5

* Neutralized and settled.

As there was some concern about toxic effects of the filter effluent on aquatic insects, the toxicity threshold was determined with *Daphnia magna* (4). The toxicity threshold value, determined as 0.65 per cent, was satisfactory, as the treated fermentation wastes would be diluted adequately by the river at low flow.

The growth on the filter stones was quite heavy at times and occasional raking was necessary to prevent ponding and eliminate strong odors. It was evident that the Stonewall plant fermentation wastes could be treated on trickling filters, but that one filter was insufficient to effect a high enough B.O.D. reduction. Other disadvantages lay in the high recirculation ratio, which would entail high plant-scale operating costs, and the heavy filter growth, which could periodically render the filters inoperable.

A decision was made to dilute the fermentation wastes with the comparatively weak general plant wastes and treat the mixture on two filters in series at lower recirculation ratios.

Treatment of Fermentation and General Plant Wastes

A second trickling filter identical to the first and two 1,000-gal. conical bottom settling tanks were installed and the system was piped for series opera-

tion. The spent fermentation broths were mixed in a 1000-gal. feed tank and fed by means of the proportioning pump into a line which conveyed the general plant wastes pumped directly from the equalization basin outfall to the first trickling filter. The pilot-plant trickling filters and the flow diagram are shown in Figures 2 and 3, respectively.

The data obtained from operation in series with the mixed fermentation and dilute plant wastes are shown in Table II.

Treatment of Combined Plant Wastes

The next step in trickling filter investigation consisted of incorporating the strong process wastes in the feed mixture. Disposal of these wastes at the Stonewall plant by evaporation and incineration has incurred a high operating cost. These wastes have an average B.O.D. of about 30,000 p.p.m., are highly toxic to aquatic life and are of dark color.

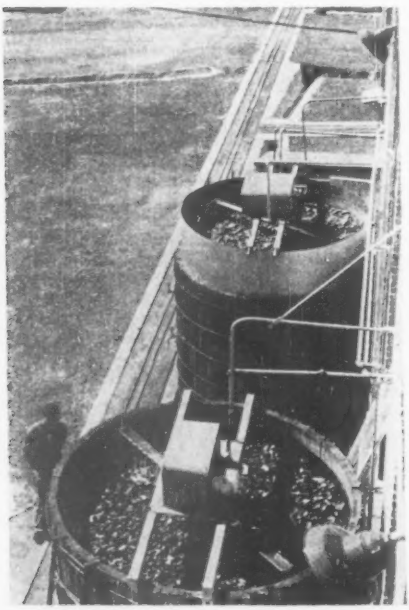

FIGURE 2.—Pilot-plant trickling filters for treatment of fine chemical wastes.

The mixture of spent fermentation liquors, equalization basin overflow, and strong process wastes subjected to trickling filter treatment had an average B.O.D. of about 900 p.p.m., with a range of 650 to 1,100 p.p.m.

The filters were operated for three months at a recirculation ratio of 5:1 and at average B.O.D. loadings of 1.65 lb. per cubic yard per day on the primary filter and 0.65 lb. per cubic yard per day on the secondary filter. The B.O.D. reduction was about 60 to 65 per cent on each filter and the overall reduction was 84 per cent. The B.O.D. of the settled effluent averaged 135 p.p.m. with a range of 100 to 155 p.p.m.

The toxicity threshold determined with *Daphnia magna* was from 25 to 50 per cent on the final effluent as compared to a threshold of less than 0.1 per cent on the raw mixed feed.

The total quantity of sludge collected daily was about 10 gal. per 1,000 gal. of raw feed. The sludge contained about 2.5 per cent suspended solids.

During this period of operation, there was no evidence of ponding or unpleasant odors. On warm days *Psychoda* flies were noticeable, but not troublesome. A search for *Sphaerotilus* growth revealed a coating on the false bottom and drain pad of the primary filter, but none at the secondary filter.

Preliminary Design Considerations

At this point a preliminary plant-scale design was considered. The tentative layout consisted of three trickling filters (6-ft. stone depth) and two clarifiers. Two of the filters and a clarifier would be primary units and the third filter and the other clarifier would be the secondary units.

Loading on the two primary filters would be 1.5 lb. per cubic yard per day and 1.35 lb. per cubic yard per day on the secondary filter. An overall B.O.D. reduction of 80 per cent could be expected.

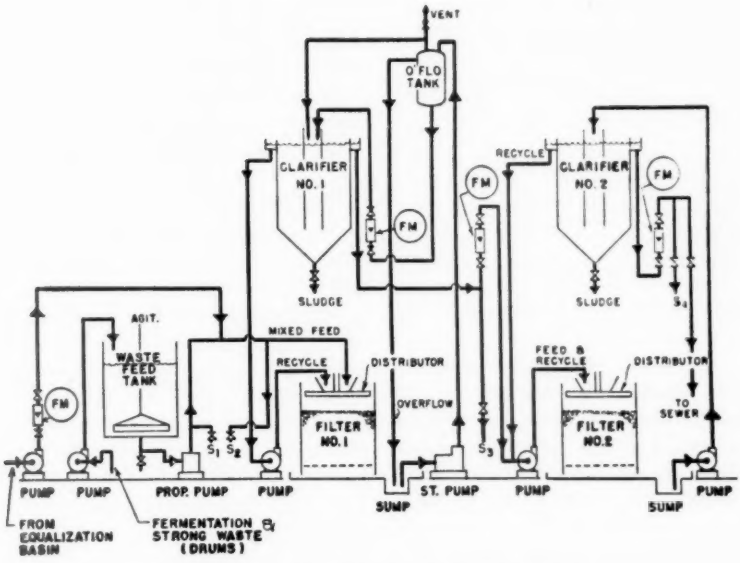

FIGURE 3.—Flow diagram of pilot-plant filters.

The following changes in the scheme of treatment directed toward reducing costs were then considered for study:

1. Elimination of the primary filter clarifier and reduction in the size of the final clarifier through the use of direct recirculation on the filters (5).
2. Reduction of the filter bed depth from 6 ft. to 4 ft. (6).
3. The B.O.D. reduction obtained through primary settling in the equalization basin.
4. Decreasing the total waste volume by excluding from the equalization basin all waters containing no B.O.D., such as cooling and jet waters.
5. Disposal of 12,000 gal. of sludge per day on cultivated land.
6. The adequacy of just primary filters in effecting a minimum B.O.D. removal of 70 per cent.

Filter Depth and Recirculation Studies

Filter depth and direct recirculation were studied simultaneously. A 2-ft. depth of stone was removed from the top of one pilot filter and a splitter box was installed to partition the raw feed into two streams of equal volume and strength. In order to operate with direct recirculation, the two pilot units were piped to return the recycle

TABLE II.—Two-Stage Trickling Filter Treatment; Mixed Fermentation and General Plant Wastes

Item	Operation No. 1	Operation No. 2
(a) No. 1 Filter Operation		
Recycle ratio	5:1	3:1
Av. B.O.D. of raw feed (p.p.m.)	700	780
Av. loading (lb. B.O.D./cu. yd./day)	1.3	1.45
Average pH	6.8	6.7
Toxicity threshold (%)	4.0	0.7
Raw feed rate (g.p.h.)	95	95
Sett. effl. B.O.D. range (p.p.m.)	115 to 330	145 to 245
(b) No. 2 Filter Operation		
Recycle ratio	5:1	3:1
Average feed B.O.D. (p.p.m.)	250	240
Av. loading (lb. B.O.D./cu. yd./day)	0.42	0.42
Sett. effl. B.O.D. range (p.p.m.)	50 to 120	5 to 125
Sett. effl. B.O.D. av. (p.p.m.)	90	115
Over-all B.O.D. reduction (%)	87	84
Av. effl. tox. threshold (%)	100	80
Gal. sludge/1,000 gal. raw feed	10	10
Sludge suspended solids (%)	3	3

TABLE III.—Trickling Filter Performance Data; 4-Ft. *vs.* 6-Ft. Stone Depth with Direct Recirculation

	Raw Feed	Effluent	
		4-Ft. Filter	6-Ft. Filter
Recirculation	—	5:1	5:1
pH	7.0	7.4	7.4
B.O.D. (p.p.m.)	1,635	230	325
Loading (lb. B.O.D.)[1]	—	2.05	1.45
B.O.D. reduction (%)	—	81	72
Toxicity threshold (%)	1	10	8

[1] Pounds B.O.D. per cubic yard per day.

liquor directly to the trickling filters and the effluent to the clarifiers.

The filters were operated in parallel for two months. The average data obtained during a part of the two months of operation are given in Table III.

Sludge Disposal Studies

Filtration and Incineration

Vacuum filtration tests on the trickling filter sludge, containing from 2 to 4 per cent suspended solids, indicated a rate of about 1 g.p.h. per square foot. Many chemical conditioning treatments (7) were investigated and a 10-fold improvement was effected with ferric chloride and lime. The sludge cake contained about 60 per cent moisture and was reduced to a soft ash by burning. This effected a complete disposal, but involved a high plant-scale equipment cost.

Digestion

Anaerobic digestion was investigated, but the 4,000 to 6,000 p.p.m. of sulfate ion in the sludge was rapidly converted to the toxic hydrogen sulfide. Digestions involving additions of iron salts to precipitate sulfides, multiple-stage operation, and intermittent areations (8) were tried but were considered rather complicated for continuous stable operation. A 70 per cent B.O.D. reduction with a 65 per cent bulk reduction was finally obtained in a single-stage digester employing a 5-day retention time and a supernatant discharge. However, there still remained the problem of disposing of one-third of the original sludge volume.

Land Disposal

Land disposal was shown to be the most practical method for disposal of the biofilter sludge. Essentially, the method involves the distribution of sludge on soil where the microorganisms present assimilate the organic materials and convert them into humus. Experimental work was started during warm summer conditions with a sludge loading of 0.02 gal. per square foot per day. Dosed sections of the experimental tract were covered with soil by tilling daily. A rapid conversion of raw sludge to humus was observed and no odor problem developed. There were no toxic effects, as evidenced by an increased earthworm population. After several months application it was evident that a higher loading could be tolerated and the rate was increased to 0.04 gal. per square foot per day with continued satisfactory results.

Since it was felt that routine cultivation on a plant scale would be impossible during unfavorable winter weather, the test plot was surface dosed for four months under winter conditions. By the end of this period a sludge mat of ⅛- to ¼-in. thickness had accumulated on the soil surface. A slight odor and some *Psychoda* flies were evident with the advent of warmer weather. These were eliminated when cultivation was resumed on a one- to two-week basis. These studies proved that surface dosing for extended periods during winter conditions was practical and that daily cultivation during warm weather was not necessary.

Sphaerotilus Studies

Conditions conducive to *Sphaerotilus* growth were studied by simulating river conditions in an artificial stream bed (9). It was demonstrated that easily assimilated nutrients supported *Sphaerotilus* at all dilutions in approximate proportion to concentration. This meant that in order to avoid *Sphaerotilus* growth, almost complete removal of such organic compounds would be required. There were indications, however, that the growth could be decreased to a negligible density by biological removal of the more easily assimilated nutrients.

Basis for Design

Sufficient data having been obtained on all phases of study, the design of plant-scale treatment facilities was to proceed based on the following conclusions:

1. A 4-ft. deep filter bed performed as well as a 6-ft. deep bed.
2. Direct recirculation of trickling filter effluent was satisfactory. Only clarification of the portion to be discharged was necessary.
3. Having obtained an 81 per cent B.O.D. reduction from single-stage filter operation, a safe average B.O.D. reduction of 70 per cent could be assumed for a plant-scale unit.
4. Design of the plant-scale units should be based on a B.O.D. loading of 1.9 to 2.0 lb. per cubic yard per day.
5. Land disposal of sludge was satisfactory on a year-around basis at a sludge loading rate of about 0.04 gal. per square foot per day.
6. A B.O.D. reduction of approximately 15 per cent can be expected in the equalization basin.

Future Considerations

Although there was no indication from pilot-plant studies that pre-aeration of the mixed wastes was necessary, this has been considered. The need cannot be established until after the currently designed facilities have been in operation for some time.

Conclusions

Pilot-plant studies at the Stonewall plant of Merck & Co., Inc., indicate that combined liquid wastes from the manufacture of antibiotics, vitamins, and sulfa drugs can be satisfactorily treated by trickling filters. This will greatly improve the character of the plant's waste effluent, resulting in an improved condition of the Shenandoah River.

Estimates of the cost of operating trickling filters for the treatment of pharmaceutical wastes are considerably lower than those of evaporation and incineration equipment.

Although the disposal of the sludge from sanitary waste treatment by incorporation in the soil has been common practice, little information is available on land disposal of sludges obtained from trickling filter treatment of fine chemical wastes. The studies conducted in connection with this project, however, show that land disposal of this sludge is feasible. Where a sufficient ground area is available, this method is preferred to those of anaerobic digestion or filtration and incineration.

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SEWAGE WORKS CONSTRUCTION AUTHORIZED IN U. S. CITIES IN 14-MONTH PERIOD

Recent release of cumulative data on National Production Authority authorizations for sewage works construction in cities of 25,000 and over makes available some interesting figures. The data reported cover the 14-month period from October 31, 1951 to December 31, 1952. Of the 560 major communities in the continental United States, Hawaii, and Puerto Rico, 134 were authorized to construct sewage works averaging $3,854,000 in cost and serving 41,830,700 persons. Included are some cities whose census population is less than 25,000, but whose systems serve 25,000 or more, as well as some sewer and sanitary districts not identifiable as cities.

Of the $869,533,000 total authorized, $516,353,000 was for projects in major cities and $353,180,000 for projects in minor cities. Breakdown figures for costs in the minor cities were not given, but in the major cities were as follows: $427,894,000 (82.9 per cent) was allotted for collection, $30,344,000 (5.9 per cent) for interception, $4,214,000 (0.8 per cent) for pumping, and $53,901,000 (10.4 per cent) for treatment and disposal. The average per capita cost for the entire authorization was $5.66, of which 59.4 per cent was for projects in the major cities and the remainder for projects in the minor cities.

Controlled materials were allotted for the authorized work as shown in Table I. The amounts of the various materials used per $1,000,000 of the total amount authorized are given in Table II.

TABLE I.—Materials Allotted for Sewage Works Construction, October 31, 1951 to December 31, 1952

Class of City	Steel (tons)	Copper (1,000 lb.)	Aluminum (1,000 lb.)	Building Materials (mil. $)	Prod. Equip. (mil. $)
Major	113,571	791.5	297.2	66.601	11.149
Minor	54,555	778.8	148.4	37.064	3.436
Total	168,126	1,570.3	445.6	103.665	14.585

TABLE II.—Material Used per $1,000,000 of Total Sewage Works Construction Authorized, October 31, 1951 to December 31, 1952

Class of City	Steel (tons)	Copper (lb.)	Aluminum (lb.)	Building Materials ($)	Prod. Equip. ($)
Major	220	1,533	575	129,000	22,000
Minor	155	2,205	418	105,000	9,000
Average	181	1,690	512	119,000	17,000

DISPOSAL OF WASTE WATER FROM OIL FIELDS IN THE COASTAL COUNTIES OF CALIFORNIA *

By Richard Pomeroy

Pomeroy and Associates, Consulting Engineers and Chemists, Pasadena, Calif.

The principal oil fields of California are shown in Figure 1. There are two major petroliferous regions: the San Joaquin Valley, producing about 40 per cent of the oil in the state, and a coastal belt which produces the other 60 per cent. This belt is about 200 mi. long and 40 mi. wide, extending from the Santa Ana River in Orange County, through the counties of Los Angeles, Ventura, and Santa Barbara, and a short distance into San Luis Obispo County. Waste water disposal from this coastal belt is the subject of this paper. According to the classification of the California Department of Natural Resources, there are 70 fields in this area, with about 15,000 producing wells.

Amount of Waste Water

Early attempts to predict brine flows from the fields had little relationship to reality, and it is still difficult to make intelligent guesses for new fields. Some become heavy water producers; others have so little water that water must be re-injected to help drive oil to the wells. In any single field the production of water generally increases as oil production declines. Eventually a place is reached where the abandonment of marginal wells offsets the increase of water production from the remaining wells, so that water output levels off and then declines. Figure 2 shows the records for the Long Beach field. Two peaks of oil production resulted from the discovery of two producing zones. Because of highly competitive drilling in the 1920's, this field is well along toward depletion even though not excessively old in years. It appears that the peak of water production has been passed.

Figure 3 shows the record of total oil and water production from the coastal belt. Oil production reached 220,000,000 bbl. in 1951, the latest year for which data are available, or an average of 600,000 bbl. per day. This is equal to 25 m.g.d. Water production is now practically equal to the oil production.

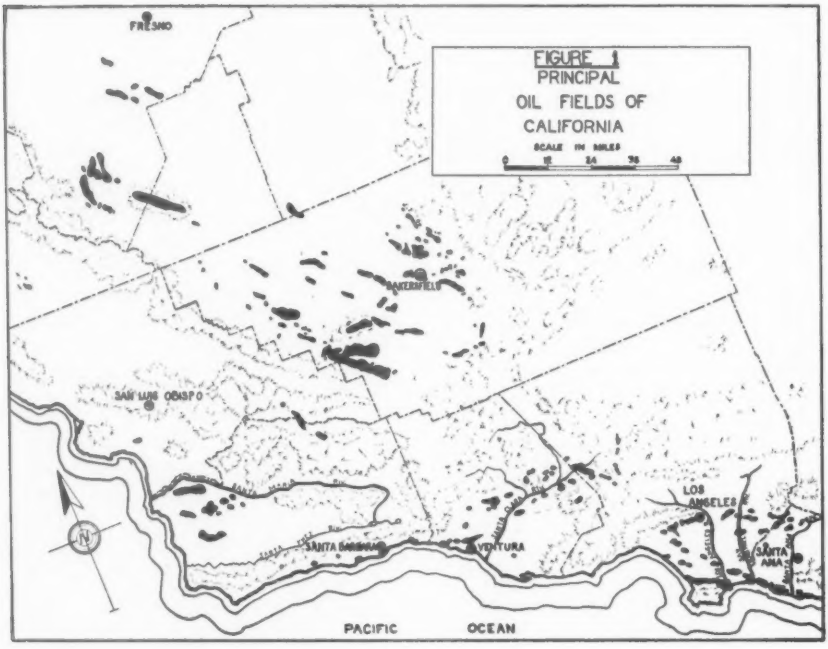
Continued increase of rate of oil production is expected, and when a peak is finally reached the production of water will continue to increase, so that it must eventually reach a flow much higher than the present total of 25 m.g.d., but it would be rash to attempt to guess just what the ultimate maximum may be.

Total waste water flow from the fields includes not only the water produced with the oil, which is shown in Figures 2 and 3, but also boiler, softener, and cooling tower wastes, waste waters from some small refining operations located in the fields, and other waters of surface origin. The present total is probably about 30 m.g.d. It should be noted that waste water flows from the major refineries are not part of the subject matter of this paper.

Routes of Disposal

The waste waters collected from the fields nearly always carry high mineral concentrations and may cause pol-

* Presented at 1953 Convention, American Chemical Society; Los Angeles, Calif.; Mar. 19, 1953.



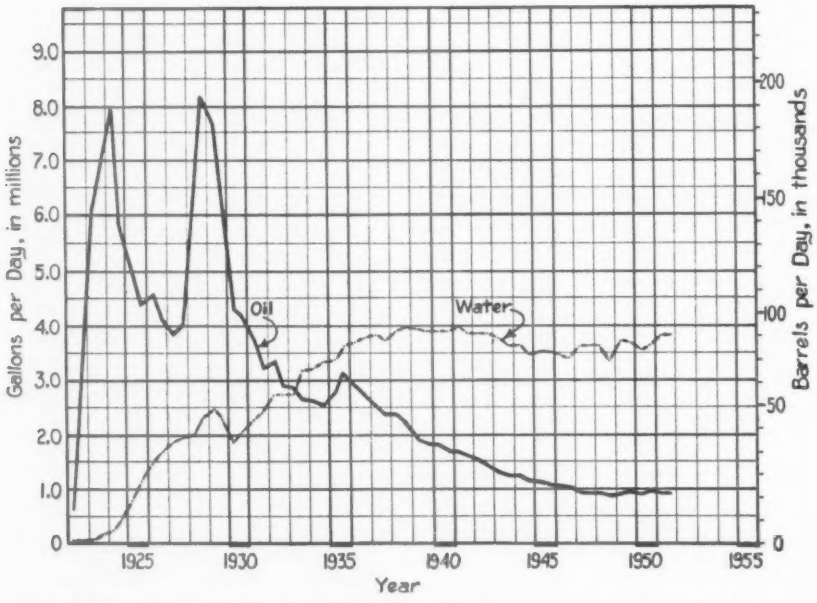


FIGURE 2.—Oil and water production from the Long Beach, Calif., oil field.

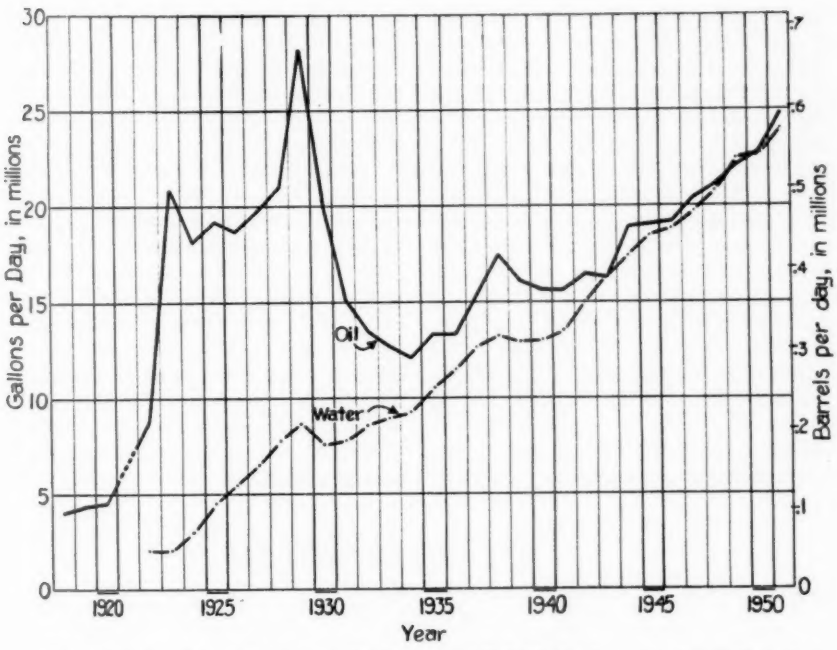


FIGURE 3.—Oil and water production from oil fields in the coastal counties of Southern California.

lution of valuable underground aquifers if not properly handled. Fortunately, the ocean is near enough to serve for final disposal in most cases, but water from some of the small fields at considerable distance from the coast must be re-injected or be discharged into formations which are geologically safe as far as ground-water pollution is concerned. The largest single re-injection operation is in the Lompoc field, where a flow of about 15,000 bbl. per day, or 0.6 m.g.d., is returned to the formation. The Torrance, Dominguez, and West Coyote fields, although in sewered areas, are re-injecting a few thousand barrels per day for secondary oil recovery. Altogether re-injection takes care of about 2 m.g.d.

The principal routes of disposal to the ocean are via public sewers, co-operative waste-water disposal associations, and many small direct discharges into tidal waters. The routes of disposal are summarized in Fig. 4.

It might seem that few technical problems of waste water disposal would arise for those oil fields which can discharge directly or indirectly into the ocean. This is not the case. Millions of dollars are invested in disposal facilities, and operating costs amount to several hundred thousands of dollars per year. There are large economic differences between efficient and inefficient handling of these wastes.

Nature of Waste Water

The most significant characteristic of the waters produced with the oil is the salt content. Salt concentrations in the Southern California fields are generally lower than in the mid-continent and Gulf Coast areas, but are still quite high, with upper limits approximating the concentration of sea water. The principal fields produce

waters with chloride concentrations of 5,000 to 15,000 p.p.m. Low salt content is found in some of the small or shallow fields, as for example at Arroyo Grande at the northern end of the coastal oil-producing belt. It is supposed that much of the water produced by this field is geologically recent recharge from the surface. Some samples are not greatly different from water produced by water supply wells in shallow aquifiers.

Iodine is high in some of the fields, reaching concentrations as high as 80 p.p.m. in individual wells. The richest brines of the Long Beach, Venice, and Inglewood fields are processed for iodine recovery in three plants of the Dow Chemical Company (2); waters in the Dominguez field are treated by the Deepwater Chemical Co. These four plants account for the total iodine production in the United States, supplying more than half of the total consumption. Much more iodine could be produced at somewhat higher cost if iodine demands made this necessary.

Sulfate is seldom present in any of the waters that have been in contact with the petroleum over long periods of time. When sulfate is found in the collected waste of an oil field, it is usually attributable to miscellaneous other wastes such as boiler blow-down, or to pumping, by the wells, of water from non-petroliferous strata, or rapid in-drawing of water into the field from non-petroliferous

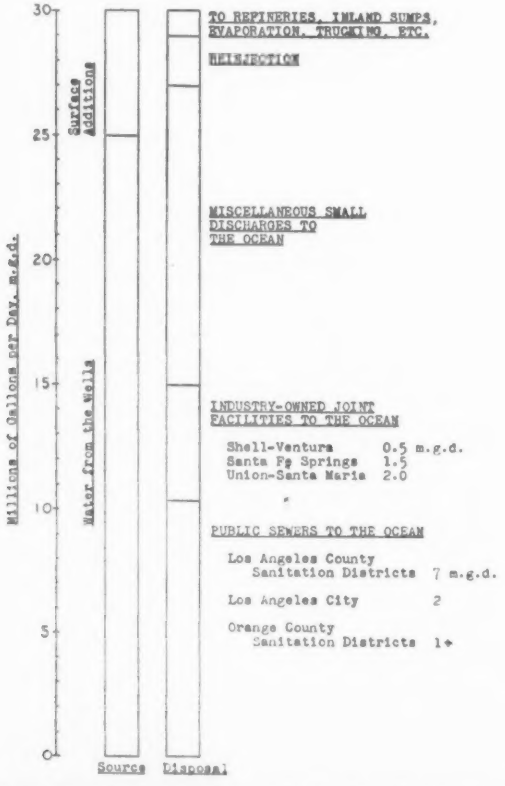


FIGURE 4.—Routes of disposal of waste waters from California oil fields.

strata. Not only is sulfate generally absent from connate brines in Southern California, but also these brines generally contain barium, in concentrations up to 200 p.p.m. The insolubility of barium sulfate prevents the co-existence of the two ions in solution.

Sulfide concentrations are low or absent in the connate waters of this area, but high concentrations may be produced by bacterial action in the waste water collection and disposal system, as discussed later.

Carbon dioxide is, of course, present in all of the waters, in amounts varying with the pressure and carbon dioxide content of the associated gas. Bicarbonate is usually several hundred p.p.m., and reaches 14,000 p.p.m. (as bicarbonate) in some samples. Hardness is high, 500 p.p.m. being typical but with some wells reaching 4,000 p.p.m. Most of the waters are saturated with lime, becoming supersaturated because of loss of gas after the water is withdrawn from the well.

Presence of ammonium ion is typical, with available data showing 25 to 100 p.p.m. Boron analyses on 70 samples taken throughout the area show 0.5 to 65 p.p.m., with a median of about 20 p.p.m. Waters with less than 5 p.p.m. of boron always contain relatively small chloride concentrations (mostly below 800 p.p.m.), but there is not much correlation between boron and chloride at the higher concentrations.

The oil field brines show substantial B.O.D., generally ranging from 100 to 600 p.p.m. by the standard 5-day test. The principal class of organic matter which appears to be responsible for this oxygen demand is made up of the anions of distillable organic acids. Most brines show the presence of these anions in concentrations ranging from 1 to 10 milli-equivalents per liter.

Water from a few wells in the De Soto sand at about 10,000 ft. in the Long Beach field and from one area in Ventura County, show organic anions in much higher concentrations. A sample from the Long Beach field showed 32 milli-equivalents per liter. It was found that this is almost entirely acetate. As acetic acid, this amounts to 1,900 p.p.m., or 0.68 lb. per barrel of water. The finding of this amount of acid in a large flow of water has aroused interest in possibilities of recovery.

Problems of Waste Disposal

The principal problems encountered in the disposal of these oil field waste waters are considered under the following headings:

1. Oil content of the waste water.
2. High B.O.D. and sulfide production.
3. Lime incrustation.
4. Corrosion.

Oil Content

Whether the waste water goes into a sewer, into a slough or drainage ditch near the ocean, or directly into the ocean at the shore, it must not carry excessive oil. Oil reaching sewage treatment plants is objectionable because excessive amounts in digestion tanks may interfere with the normally active digestion in the scum layer by oil impregnation of the solid particles. It is not destroyed in the anaerobic digestion process, but remains in the final sludge. Some hydrocarbon oil is inevitably present in all digested sludge, and is not noticeable in ordinary amounts (up to 5 per cent) in the final dried product. Yet even in small concentrations oil has caused accelerated deterioration of rubber structures in sludge filtration and drying equipment, and any unnecessary increase in the amount present in the sewage should be avoided.

If the waste water is discharged into drainage ditches or sloughs, oil may accumulate in eddies or behind obstructions. It may destroy vegetation and small animal life serving as food

for larger animal life, or may damage spawning grounds. It may get into the feathers of aquatic birds and prevent them from flying. It is likely to destroy whatever esthetic or recreational possibilities may exist.

If the waste water is discharged into harbors, an excessive oil content may contribute pollution which is unsightly and which coats mooring lines and messes the sides of pleasure craft. In general, however oil field waste water has been only a minor contributor to harbor pollution in comparison with other sources. If discharged at the shore, oil may foul bathing beaches.

This array of hazards from oil pollution shows at once that sewering to the ocean is by no means a carefree operation. Yet no trouble arises if it is properly done.

In preparing water for discharge into the sewer, plain gravity separation normally suffices.

Modern designs for gravity separators are simpler than the older units with multiple baffles, cascades, rock beds, etc. Rohlich and Ingersoll (3) have shown that the same design principles apply as in the settling of solids. A single basin with good inlet baffling to still the inlet velocity and a skimming baffle at the outlet end gives as good results as more complex structures. With water of high oil content, however, a small first stage followed by a larger second stage may be advantageous so that the large bulk of the oil may be removed more easily from the smaller area. This is not important if automatic mechanical skimming is used, but such skimming is not common in the oil fields. Some of the new separators are built with a single compartment, but others retain at least the two-stage features. Circular clarifiers are used in a few places.

The seriousness of the presence of hydrocarbons in the atmosphere in Los Angeles County, now recognized as a principal factor leading to formation of "smog," has presented new problems in separator design. Air pollution control authorities are now insisting that evaporation from separators be prevented. A procedure which will be satisfactory in many cases will be to use a small initial covered compartment, which will take off most of the oil, after which the oil content of the water will not be great enough to be the cause of any substantial atmospheric pollution when the water goes to a large compartment for final oil removal.

Wherever the water in an effluent channel passes under an obstruction or wherever there is an eddy, oil accumulates on the surface. This always gives the impression that one more skimming would greatly improve the water. Actually, a hundred such additional oil traps would each allow the skimming of a little more oil, for the separation of the oil from the water approaches zero asymptotically. The best plan is to build one good separator and then avoid conditions allowing conspicuous accumulations of oil in the effluent channels.

Weston (4) has pointed out that rates of separation must be considered in judging separator performance. In a recent article the author (8) described techniques for measuring rates of separation and have shown their relationship to separator design. Generally, oil field waste waters should be satisfactory for discharge to the sewer if they have passed through a well-maintained separator with a capacity factor of 20 min. per foot. (This may be looked upon as minutes detention time per foot of depth; thus, if a tank is 6 ft. deep this capacity factor will result in a detention time of 120 min.)

For discharge to a harbor or at shore, longer times may be needed. Discharge into an estuary or slough may require a very long detention time, or a degree of treatment greater than can be accomplished economically by plain gravity separation.

Chemical flocculation is used when gravity separation will not suffice. Ferric chloride is used in some places, as at the iodine plants (3). Aluminum sulfate is used in a number of other installations. The floc is generally removed by settling, but Deepwater Chemical Co. has been using flotation for a number of years (5), and this principle is now being used to an increasing extent. For the highest degree of clarification, as in the preparation of water for injection for secondary recovery, flocculation and flotation or sedimentation is followed by filtration through sand or diatomite.

Effluent strainers of excelsior, straw, or retted gourds are often used in the fields to take out more oil. When the surfaces of the strands of these materials are clean they have an affinity for oil, but the capacity is exhausted as soon as the surfaces are coated. If the amount of oil removed when these filters are replaced is ascertained, the effect can be appraised. Very commonly the effect on the water is small because renewal is not frequent enough. When a high-quality effluent is desired, these filters are of some use in small installations, provided they are renewed as rapidly as the surfaces become coated with oil.

A thorough job of purification has been done by the Santa Fe Springs Waste Water Disposal Co. on a flow of 3.5 m.g.d. This has been necessary because the effluent discharges (all of it until recently, part of it now) via 17-mi. pipe lines into a tidal slough at Seal Beach. Humphreys and Rawn (1) described the installation in 1941 of the plant, which would flocculate the water with aluminum sulfate and then filter it through a magnetite filter. The alum floc proved to be very small and fragile, and was not adequately removed by filtration. An intensive period of experimentation was then undertaken, in which a wide variety of materials suggested as coagulants were tried. Finally the use of activated silica (6), which was just becoming known at that time, was tried in conjunction with alum. The results were spectacular. With this combination the floc, which was formerly very fine and slow settling, became large, compact, and heavy. The plant was partially rebuilt in 1944 to provide sedimentation after the flocculation step. Chemical dosage consists of 30 p.p.m. of alum and 6 p.p.m. of activated silica. Skimming and sludge removal is accomplished mechanically by traveling-bridge equipment. Removal of most of the floc in this way allows the filters to produce a clear water, so that the total oil content of the effluent has averaged about 3 mg. per liter.

High B.O.D. and Sulfide Production

The B.O.D. of the waste waters ranges from low values up to 600 p.p.m. in some of the fields, and up to 4,500 p.p.m. or more in the case of individual wells producing waters of high organic anion content. This oxygen demand is one of the principal obstacles to discharge into tidal sloughs, for it may cause a rapid disappearance of dissolved oxygen. In many places the disappearance of oxygen is followed by sulfite generation. Even where this does not occur, the loss of oxygen destroys aquatic animal life.

An extreme example of the effect of the oxygen demand of an oil field waste water was well illustrated in the disposal of effluent of the Oil Operators, Inc., into the Los Angeles River.

A series of tests in August, 1949, by the Bureau of Sanitary Engineering, California State Board of Health, showed surprisingly rapid oxygen depletion in the river. The meager flow in the river was about 6 to 8 m.g.d.; to this was added 2.75 m.g.d. of oil field waste water. The 5-day B.O.D. of the mixture was about 150 p.p.m. The river above this discharge was saturated with oxygen, but oxygen depletion in the stream was rapid. Objectionable oxygen reduction or de-

pletion extended into the tidal waters over an area of 50 acres.

By classical calculations of oxygen depletion in streams, it would appear that disposal into the river would not cause nuisances, but the conditions actually existing were the basis of complaints from the pollution control authorities, citing oxygen depletion, sulfide generation at certain times, unpleasant appearance because of milkiness of the water, slime growths on the bottom, and rattail maggots coming from these slimes. When Oil Operators became aware of the unexpected conditions resulting from the phenomenal biological behavior of the mixture of oil field and river waters, extensive studies were made of possible remedial measures, leading eventually to arrangements for disposal into a trunk sewer of the Los Angeles County Sanitation Districts.

Sulfide generation is a serious problem in many places. However, the waters produced with the oil in this area rarely contain sulfide, and are devoid of sulfate or any other sulfur compounds. Additions of sulfate by adding cooling waters and other surface waters afford the possibility of biological sulfide generation. In many places the barium content is great enough so that substantial sulfate additions are precipitated. In the Long Beach water handled by Oil Operators, Inc., a surplus of barium remains after all additions of sulfate-containing waters, and no sulfide generation has occurred except under some conditions after addition to the Los Angeles River. In other fields the barium of the brine has been hopelessly overbalanced by sulfate additions, as at Santa Fe Springs, but even here the amount of sulfide produced has sometimes been limited by the supply of sulfate present. In some cases, as in the West Coyote field, it has been possible to observe the change, over a period of time, from an excess of barium with no sulfide generation, to an excess of sulfate with sulfide generation. Rate of sulfide generation is not materially affected by sulfate concentration as long as sulfate is present.

The effects of B.O.D., temperature, and aeration by velocity of flow or otherwise, are related to sulfide generation in the same way as in the handling of sewage, and the same control measures are generally applicable. These include: design to avoid anaerobiosis, design to avoid release of H_2S if the water contains sulfide, chemical shock treatments of pipe lines, reduction of temperature, reduction of B.O.D., elimination of sulfate, use of toxic chemicals, chlorination, sodium nitrate, precipitation by metallic salts, and others. A number of examples may be cited. A Union Oil Co. discharge from Rosecrans field into a sewer caused sulfide generation in the sewer. The temperature of the waste was reduced from 130° to 90° F., with practical elimination of the sulfide condition. British-American Oil Co. adds zinc chloride to a small flow to change soluble sulfide to insoluble zinc sulfide. The Hall Oil Co., operating an area of the Wilmington field, conveyed the waste water in ditches to a separator before discharge to the harbor, but experienced sulfide generation in the ditches. The pumping of sea water into the upper ends of these ditches reduced the B.O.D. and increased the flow, effectively eliminating sulfides. Chlorine is often used to remove sulfides and prevent slime growths in injection water, but chlorine is rather expensive for removing any substantial concentration of sulfide from large flows, and is not practical as a preventive in long pipe lines. Other toxic chemicals have been tried, but have not proved advantageous for sulfide control.

Shock treatment by lime has come to be an important method of sulfide control in sewers in Southern California, and is equally applicable in oil field waste water lines. Treatments must be given at intervals ranging from

three days to a week, with the shorter times required in the warmer waters. Control of sulfide generation in the line from the West Coyote field to the Santa Fe Springs system depends in part upon lime treatment. The Santa Fe Springs system tried lime for a time in the effluent lines to the ocean and found it effective, but lime sludge deposits at the discharge end became objectionable, so this could not be continued. The lines are treated periodically with sulfuric acid for scale control (see next section), and this also suppresses most of the sulfide generation.

Sodium nitrate has proved effective, but generally rather expensive, for keeping sewers free of sulfide. It may prove advantageous as a supplement to shock lime treatments, for after such treatments the generation of sulfide builds up again slowly. The use of nitrate in graduated amounts serves to hold sulfides to zero until it becomes more economical to apply another lime treatment rather than to continue to increase the nitrate dosage. This combination treatment has been used in the West Coyote waste water line for several years.

Lime Incrustation

The connate waters in many of the fields are saturated with lime. Loss of carbon dioxide when the water is brought to the surface may lead to supersaturation, although this may in part be offset by reduction of temperature. Incrustation of pipe lines with lime has been a serious problem in some fields, where it has been necessary to ream out these accumulations. A 6-mi. pipe line from the Montebello field to the Santa Fe Springs Waste Water Disposal Co., carrying 23,000 bbl. per day, accumulated 5 to 10 tons of lime per year, and similar conditions exist in pipe lines within the Santa Fe Springs field. The two 17-mi. effluent lines from the Santa Fe Springs plant to the ocean accumulated a total of about 100 tons per year, and had to be cleaned mechanically from time to time at an average annual cost of $7,000.

Furthermore, when the Santa Fe Springs Association installed the magnetite filters in 1941, incrustation of the magnetite sand and the brass screens supporting the sand was also a problem. It was found that slight acidification of the water for a short time at intervals of a few days would prevent lime accumulation. It appears that the lime accumulation deposited in one week will dissolve in 1 hr. when the pH is lowered to 4. This is much more economical than continuous pH reduction to a level that would prevent any accumulation, and by using an industrial waste acid it proved to be a very economical substitute for the mechanical cleaning previously required in the effluent lines. The treatment is applied in concrete structures. Over a period of 10 years the surface of the concrete has suffered attack, but not to a serious degree. The effluent pipe lines are of clay, so are not harmed. The shock acid treatments, like lime, destroy sulfide-producing slimes and eliminate most of the sulfide generation that otherwise would occur in these lines.

The Union Oil Company for a time tried 1 p.p.m. of tetrasodium pyrophosphate for scale control in a pipe line, but it did not prove effective. Intermittent acid treatment was then adopted.

Waste water from the Rosecrans field caused lime accumulation in a trunk sewer. The condition eventually corrected itself when increased sewage flow provided enough dilution. Many other cases of trouble with lime might be cited.

Corrosion

Corrosion problems in the handling of the oil field waste waters are generally avoided by giving attention to the established principles of corrosion reactions.

In one location a steel pipe was allowed for a time to flow partly filled with water of high sulfide content. Under these conditions hydrogen sulfide escaped from the water and oxidized to sulfuric acid on the walls of the pipe, causing rapid corrosion. A constricted outlet was placed on the discharge end, filling most of the pipe with water, thus protecting the filled section against corrosion.

Santa Fe Springs Waste Water Disposal Co. experienced much exasperating corrosion of the brass screens of the magnetite filters. These screens are slotted brass sheets with openings 0.012-in. wide. Because of the filter grading, corrosion to the extent of a few thousandths of an inch is serious. Difficulty was first experienced with accumulation of lime in the slots. Acid treatments (see preceding section) were used to keep the screens open. Then corrosion occurred at a rate sufficient to ruin the screens in about 18 months. The corrosion was not directly attributable to the acid treatment. In the course of experimentation by the author, tests were developed for measuring the corrosiveness of the water toward brass over short periods of time. Reproducible results were attained, but the water showed marked variations in corrosiveness over periods of a few hours. Sulfide was involved in the corrosion reactions, but the reasons for fluctuating rates remained obscure.

To check this damage, cathodic protection was installed using rectified current and sacrificial iron anodes under the screens. The problem of lime accumulation then was aggravated by the cathodic action. For this reason complete protection was not possible, but a compromise condition was established which avoided excessive liming and approximately doubled the life of the screen. A current density of about 6 milli-amperes per square foot of screen is used.

Co-operation with Pollution Control Agencies and Sewer Authorities

The first task of a waste disposal engineer is to find how to meet the aims of public welfare while at the same time minimizing the need for elaborate purification installations. His second task is to design what is truly needed. He must co-operate with the public agencies in attaining their aims, but a purely passive sort of co-operation is not implied. There must be a recognition of the fact that complex technical problems are involved, and that the best ability of the industry as well as the public agencies may be needed to find the best answers.

With rare exceptions, the public agency welcomes the aid which a competent industrial representative can give in helping to provide the technical foundation for decisions which must be made. The public agency engineers find themselves confronted time and again with new problems requiring research that they cannot immediately supply. The complex effect of a proposed plan of disposal may not be readily apparent. If a decision must be made promptly, the wise administrator is conservative and plays safe by setting rigid requirements, with the result that the industry may carry a burden that further study would show to be unnecessary. The industry then complains of the restrictions under which it must operate, but it should not do this until it has qualified itself to show that better decisions are possible, keeping in mind the objective of public welfare, and has conferred with the public agency on the problems.

The complexity of problems of this sort is sometimes amplified by the number of agencies involved. In the case of disposal of Oil Operators' effluent into the Los Angeles River, at least 12 agencies were involved, ranging from local to national and concerned with aquatic life, public health, atmospheric pollution, flood control, shipping, ground-water pollution, and rec-

reation. Effective efforts have been made to simplify these complexities by clearing-house committees. Much has been done along this line by the Regional Water Pollution Control Boards, and also, in Los Angeles County, by the Industrial Waste Division of the County Engineer's office. Seldom does an industry need to go to more than one agency to get clearance from all.

Conditions and terms for disposal into sewers are also subjects for conferences. One of the problems in Los Angeles County was the rights of oil fields to use the sewers for waste water disposal. In the earlier years of oil development the Sanitation Districts administration was fearful of excessive demands upon sewer capacity, which probably would have been made if unrestricted use of the sewers had been permitted. Also, there was no great need for use of Sanitation District sewers by oil fields in areas then reached by these sewers. Consequently, the oil field brines were classified as natural waters and not as sewage. Eventually the problem was considered in conferences and the Districts agreed to accord each field a proportional right in the total sewer capacity on the basis of the ratio of the assessed valuation associated with oil production to the total assessed valuation of the District where the field is located. These proportional rights are accorded to the field as a whole. In general the producers in each field must organize themselves as a unit and deal through one representative. In many fields this proportional right is adequate to care for all of the water. In other fields it is not. In these cases the producers may pay the Districts for disposal of the excess, as at Long Beach, or they may use other routes of disposal, as Santa Fe Springs Waste Water Disposal Company, which puts about one-half of the flow from its plant into the sewer and the remainder into the ocean through one of its old pipe lines.

The Sanitation Districts also have shown a sincere desire to find the most practical quality standards for discharges to the sewer. An old standard specified an upper limit of 25 p.p.m. (milligrams per liter) of oil. It was recognized that this often placed an unnecessary burden on the industry without corresponding benefit to the Districts. Following development of the floatable oil test, the Districts adopted a limit of 10 p.p.m. of floatable oil and up to 600 p.p.m. of total oil (7)(8). This considerably eases the treatment problem for both oil fields and refineries. Plain gravity separation in separators of reasonable size will produce an effluent within these standards in nearly all cases.

Summary

Oil fields of the coastal counties of Southern California produce about 220,000,000 bbl. of oil in a year, which is about 60 per cent of California's total production. This is equal to 25 m.g.d. of oil. It is accompanied by production of water in volume now very nearly the same as the volume of oil. Total waste water flow from the fields, including some surface waters, is 30 m.g.d. or more. When oil production reaches a peak and begins to decline, water production will continue to rise, so that it will eventually reach a total much higher than the present flow.

A small amount is re-injected, and some is discharged inland under circumstances where it is supposed that ground-water pollution will not result. About 27 m.g.d. goes to the ocean via sewers, sloughs, harbors, or shore discharges on the open coast. Problems of oil content, oxygen depletion and sulfide generation, lime incrustation, and corrosion must be properly handled to avoid nuisances or expensive operations.

The Los Angeles County Sanitation

Districts, receiving about 7 m.g.d. of oil field waste water into their main disposal system, have liberalized requirements for admission of these wastes into the sewer, by introducing the "floatable oil" test.

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THIRD MCA WATER POLLUTION ABATEMENT MANUAL

A healthy trend in water pollution abatement laws is reported by the Manufacturing Chemists' Association in the third in its series of Water Pollution Abatement Manuals. The new Manual W–3, on "Neutralization of Acidic and Alkaline Plant Effluents," indicates that the trend of late is toward a policy which takes into account not only the characteristics of plant effluents but also the capacity and potential use of the receiving water.

The manual recognizes that a widespread source of stream pollution is the discharge of acidic and alkaline plant effluents. Action of effluents may kill fish or alter vegetative and animal life to destroy their sources of nourishment. High acidity may also corrode vessels, marine structures, and pumping installations, and make treatment for water supply more difficult. Alkaline effluents are not as widespread or in as large a volume as acid effluents.

Manual W–3 sets forth a program for neutralizing industrial wastes to further the purification of streams, describes laboratory and engineering studies to be undertaken prior to treating polluted water, indicates general methods of treatment for acidic effluents and the equipment required, and includes a table listing various alkalies to be used in neutralizing acidic effluents, together with current market prices for these chemicals.

Two sections of the manual are concerned with the process for neutralizing alkaline effluents and include a description of insoluble sludges resulting from neutralization.

Copies of two previous publications, Manual W–1 entitled "Organization and Method for Investigating Waste in Relation to Water Pollution," and Manual W–2 entitled "Insoluble and Undissolved Substances," priced at $0.20, and the new Manual W–3, priced at $0.25, may be obtained from the Manufacturing Chemists' Association, 1625 Eye Street, N. W., Washington 6, D. C.

WATER AND WASTE IN THE WOOD PULP INDUSTRY *

By Harold R. Murdock

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Two major chemical processes are used in industry for conversion of wood to cellulose fibers. The older method, discovered in 1867, is called the sulfite process because calcium bisulfite and free sulfur dioxide are the active chemicals in the cooking liquor. The other process, known as the kraft or sulfate process, was not used commercially in the United States until 1908. The name sulfate is derived from the use of sodium sulfate as the make-up chemical, commercial sodium sulfate being called "salt cake." The term "kraft," which means strong, is frequently used to denote the sulfate process. It is used in this discussion, therefore, to differentiate more clearly between the two similar names sulfate and sulfite.

There is another interesting difference between the two processes. From inception, the kraft process has possessed a practical method for converting spent cooking liquor into chemicals for re-use in the digester. Today, this method is a vital economical factor in operating the kraft process. On the other hand, the sulfite process has never had until recently an economical means for reclaiming or even a satisfactory means for disposing of sulfite waste liquor. Consequently, the sulfite process has been a serious contributor to the pollution of many streams in the United States. The recent growth in the nation's industrial activity has tended to emphasize this condition and necessitated that the sulfite wood pulp industry find remedial measures or eventually face mandatory orders from state agencies to cease operation.

Development, 1932–1952

Years ago, most pulp mills in the United States were located on streams providing an abundant supply of clean process waters. Stream pollution was not a troublesome matter. It was common practice to discharge the digesters into a series of large tanks, drain off the spent cooking liquor as much as possible, and then wash the pulp by countercurrent displacement with copious amounts of clean water. In the sulfite process both the strong spent cooking liquor and all the wash waters were discharged directly to the streams without treatment. In the kraft process, for economic reasons only the first draw of strong spent cooking liquor was segregated for evaporation and incineration in order to recover some of the cooking chemicals for re-use. The weaker wash waters were purged to the stream without treatment. Nobody bothered the pulp mill about downstream water conditions so there was little incentive to abate the pollution and no desire to make capital investment in chemical recovery beyond the point dictated by economics and competition. Water was abundant and stream pollution was an impractical subject for discussion.

In the 1930's things began to change. Consumers asked for more strength, better tear, and whiter color in many paper products. The printer desired

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better printability to meet the new ideas of advertisers, the grocer demanded stronger wrapping paper and bags for his customers, and the wooden box gave way to paper cartons so that the paper box maker needed strong paperboards. Business appeared to be entering a new era of prosperity.

To meet this consumer demand for higher qualities in wood pulp, producing companies examined their processes carefully. By experimentation in the mills, together with cooperation from equipment manufacturers, pulp mills succeeded in producing better and cheaper wood pulps. Some of the larger mills were stimulated to establish research staffs to further explore the technology of wood pulp manufacture.

Following this awakening of the industry to technological improvements, quite different conditions occurred in the sulfite wood pulp industry than took place in the kraft industry. This is shown in Figures 1 and 2 and Tables I and II.

From these data certain trends are apparent. Installed sulfite pulp capacity increased slowly from 1932 to 1940 and then in spite of a heavy demand for wood pulp, capacity has stood practically constant. This early increase in capacity was probably due

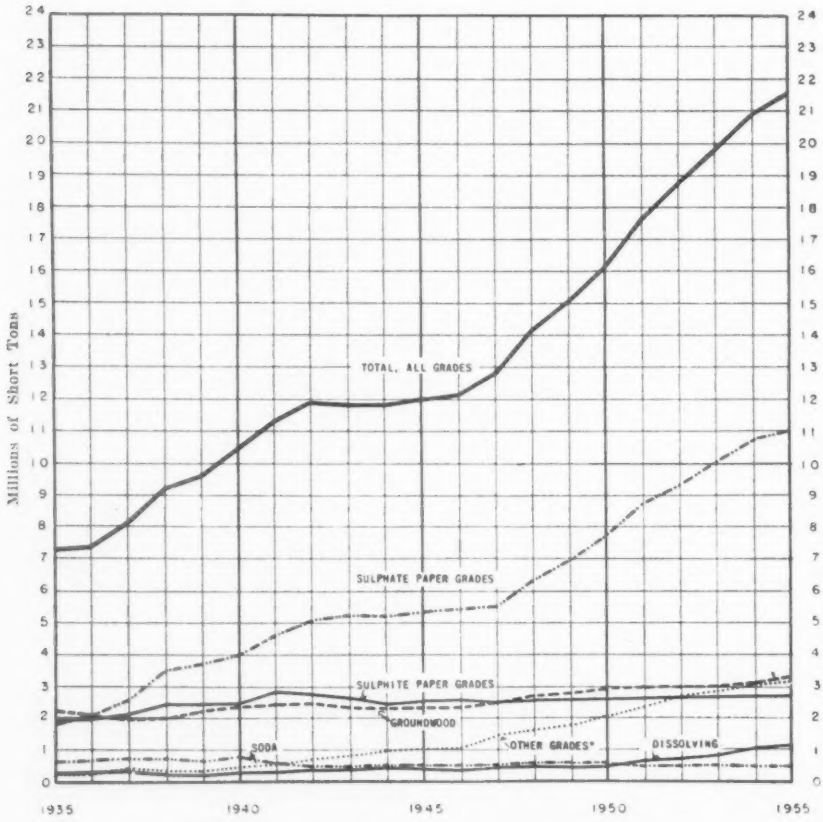

FIGURE 1.—United States annual wood pulp capacity. (Source: United States Pulp Producers Association, Inc.)

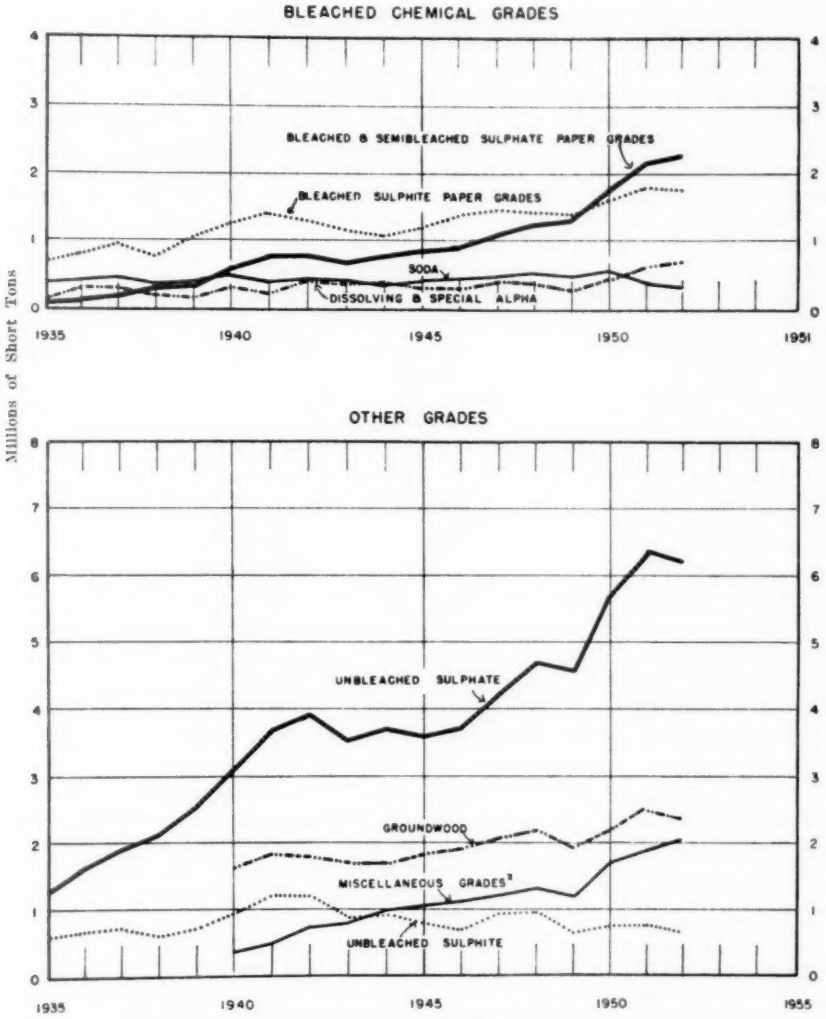

FIGURE 2.—United States wood pulp production, by grades. (Source: U. S. Bureau of the Census.)

to better mill operation resulting from able research studies. Few new sulfite mills were constructed. A moderate increase in sulfite production in all three grades is evident before 1941, which was followed by a decrease in unbleached sulfite production and a modest increase in bleached and dissolving grades that compensated for the lower unbleached sulfite production. The sulfite wood pulp industry appears to have stagnated for reasons not related to the tremendous demand for wood pulp during the past 20 years.

On the other hand, the younger kraft pulp industry has moved forward with rampant enthusiasm. In 1932, the installed capacity was only

1,600,000 tons. In 1938, only six years later, kraft pulp capacity exceeded the highest production capacity ever reached by the sulfite pulp industry. From 1932 to 1942 kraft capacity increased 3.2 times and in the 20-year period from 1932 to 1952 installed kraft capacity increased 5.8 times.

Why has the sulfite wood pulp industry not shown a healthy growth pattern similar to the kraft pulp industry? It is not due to lack of quality or inability of sulfite pulps to compete with kraft pulps.

To prove this point, consider the competitive situation existing between the two bleached pulps. Table I shows that bleached sulfite production expanded 1.3 times in the period 1942 to 1952. During this same period, bleached kraft production increased 3.2 times, whereas unbleached kraft increased only 1.6 times. Both bleached kraft and sulfite sell at identical market prices of $140 per ton delivered, while the comparable northern unbleached kraft and sulfite both sell at $120 per ton delivered. Lack of capacity expansion in the sulfite industry does not appear to be due to pulp quality or price advantages between these two types of wood pulp. It is true that the southern pines and the firs of the Pacific coast are more refractory towards the sulfite process. But evidence is not entirely lacking to show that the sulfite process can be modified so that these resinous woods can be converted into commercial wood pulps competitive with the kraft progeny, provided resourcefulness in research is applied with the same emphasis that has been given the kraft process. Stream pollution is the deterrent which has stifled research enthusiasm.

During the 1930's, in those places where pollution was arousing public anger, people were told that the problem of sulfite waste liquor disposal was complicated and that pulp mill chemists and certain universities were studying the problem, so corrective measures could be expected. Such appeasements merely delayed the matter. Later more forthright efforts were made. In Wisconsin the sulfite mills recognized that the problem demanded

TABLE I.—Sulfite Wood Pulp Production in the United States [1]

Year	Capacity (tons)	Production (tons)				Operation (%)
		Dissolving[2]	Bleached	Unbleached	Total	
1932	2,155,665	596,937		548,702	1,145,639	53
1937	2,493,831	353,640	995,029	791,575	2,140,244	86
1938	2,650,585	228,261	776,360	601,855	1,606,476	60
1939	2,664,504	193,420	1,023,829	729,203	1,946,452	73
1940	2,891,432	326,729	1,285,360	995,700	2,607,789	90
1941	3,138,000	260,690	1,442,441	1,215,649	2,918,780	93
1942	3,189,150	403,723	1,313,483	1,213,066	2,930,272	92
1943	3,040,097	390,423	1,162,773	883,306	2,436,502	80
1944	2,906,740	447,487	1,075,734	862,928	2,386,149	82
1945	2,880,195	382,618	1,161,144	815,969	2,359,731	82
1946	2,907,724	316,573	1,375,504	784,391	2,476,468	85
1947	2,891,942	407,387	1,494,558	894,017	2,795,962	97
1948	2,978,355	419,683	1,489,719	901,814	2,811,216	94
1949	2,981,055	374,050	1,454,971	707,263	2,536,284	85
1950	3,049,865	478,849	1,628,692	740,895	2,848,436	93
1951	3,225,905	616,202	1,760,685	764,640	3,141,527	97
1952	3,349,356	706,033	1,691,523	673,453	3,071,009	92

[1] Source: United States Pulp Producers Association, Inc.
[2] Includes special alphas and paper grades.

TABLE II.—Sulfate Wood Pulp Production in the United States [1]

Year	Capacity	Production (%)				Operation (%)
		Bleached	Semibleached	Unbleached	Total	
1932	1,590,619	62,251		966,595	1,028,846	65
1937	2,531,102	215,150		1,923,937	2,139,087	85
1938	3,471,185	320,513		2,122,538	2,443,051	70
1939	3,681,989	424,453		2,538,204	2,962,657	80
1940	3,989,514	453,282	131,322	3,163,378	3,747,992	94
1941	4,661,400	659,194	163,915	3,703,502	4,526,611	97
1942	5,092,600	652,590	158,862	3,926,814	4,738,266	93
1943	5,184,851	602,149	147,040	3,486,535	4,235,724	82
1944	5,161,694	644,946	144,262	3,739,602	4,548,810	88
1945	5,298,555	705,104	148,540	3,618,231	4,471,875	84
1946	5,377,079	749,822	152,337	3,685,857	4,588,016	85
1947	5,495,495	908,911	193,156	4,254,643	5,356,710	97
1948	6,289,527	1,040,055	224,751	4,748,890	6,013,696	96
1949	6,980,819	1,118,282	263,637	4,595,362	5,977,281	86
1950	7,671,218	1,432,945	359,917	5,708,567	7,501,429	98
1951	8,710,956	1,899,014	293,584	6,379,172	8,571,770	98
1952	9,316,407	2,082,844	275,062	6,210,798	8,568,704	92

[1] Source: United States Pulp Producers Association, Inc.

full attention of specialized technical men. In 1939, these mills organized the Sulfite Pulp Manufacturers Research League, Inc., with specific instructions to the staff to make a comprehensive study of the entire problem. In cooperation with the Institute of Paper Chemistry at Appleton, Wis., this research group has examined many promising possibilities for the utilization as well as disposal of sulfite waste liquor. In 1935, the Howard Smith Paper Mills, Ltd., at Cornwall, Canada, experimented on the substitution of magnesium for calcium in sulfite pulping liquors. It was pointed out that magnesia sublimes with the combustion gases during the burning of magnesium sulfite liquors in recovery boilers and that the magnesium oxide and sulfur dioxide could be recovered from the waste gases for re-use in the process. A semi-commercial pilot plant was built at Cornwall in 1937 jointly with the Babcock and Wilcox Company of New York, who had been experimenting on burning sulfite liquor in steam boiler units. In 1942, these two companies consolidated their knowledge with Weyerhaueser Timber Company, which had been studying independently this magnesia method at the Longview, Wash., pulp mill. In 1943, the forward looking executives of the industry organized the National Council for Stream Improvement of the Pulp, Paper and Paperboard Industries, Inc., for the explicit purpose of solving pollution problems within the pulp and paper industry. Today the member mills produce more than 95 per cent of the pulp and paper produced in the United States. Investigation of sulfite waste liquor is an important part of the National Council research activities. Many individual mills are also investigating the problem seriously relative to their local conditions. It is apparent, therefore, that the sulfite wood pulp industry currently is not neglecting to search for a practical answer to the exigency.

Sulfite Waste Research

A brief review of some of the accomplishments of these various study groups testifies that the sulfite wood pulp industry is technically making splendid progress. Paramount to the economical recovery of sulfite waste

liquor is the objective to obtain a high percentage of the soluble wood solids as strong collected liquor. Already a few progressive mills have taken such steps. When the digestion of the wood is completed, the digester is relieved to approximately atmospheric pressure. The contents are then flushed into a receiving tank with strong cooking liquor collected from previous cooks. A pulp suspension of 3.5 per cent permits ready pumping of the digester contents onto a vibrating screen, which removes the large knots of undigested wood. The pulp is then separated from the liquor by filtration on two or more stainless steel rotary vacuum washers suspended over concrete vats lined with acid-proof tile. The wash water flows countercurrent to the flow of pulp, so that the filtrate leaving the system discharges from the washer that receives the pulp and liquor suspension discharged from the digester. By this means a collected liquor of 10 to 14 per cent solids is obtained, representing about 70 per cent of the total spent liquor produced in the digestion process. This procedure simulates kraft mill practice, except that expensive stainless steel and other acid-proof materials are essential for practical performance.

Table III shows the quantities of the various chemical components produced during a single day's operation in the sulfite mills within the United States. Collected strong liquor is based on a 70 per cent recovery by use of the series of vacuum washers.

TABLE III.—Soluble Wood Substance and Cooking Chemicals Present in One Day's Production of Sulfite Waste Liquor in the United States [1]

Component	Collected Strong Liquor (tons)	Weak Liquor to Stream (tons)	Total (tons)
Wood sugars	1,400	600	2,000
Lignins, etc.	5,600	2,400	8,000
Lime	700	300	1,000
Sulfur	472	203	675
Total solids	8,172	3,503	11,675

[1] Basis: 9,000 tons sulfite pulp and 34 m.g. of sulfite waste liquor from digesters.

The Wood Sugar Fraction

Because the wood sugar content accounts for about 50 per cent of the 5-day B.O.D. of sulfite waste liquor, utilization of the sugar fraction has received attention from some sulfite mills. Three sulfite pulp mills in North America have constructed full-scale ethyl alcohol plants to convert the wood sugars in their waste liquor. Under present market conditions these plants are profitable, but competitive alcohol production using petroleum refiner residues has deferred other mills from adoption of the alcohol procedure (3).

The torula fodder yeast method for consuming sugars appears to offer a more assuring market. In 1948 the cooperative Wisconsin mills organized the Lake States Yeast Corporation and erected a torula yeast plant at the Rhinelander Paper Company with a capacity of 5 tons per day (4). Today the Rhinelander company owns the plant and is desugaring all of the sulfite waste liquor (6) produced in its sulfite pulping operations. A few months ago Hoberg Paper Mills, Green Bay, Wis., announced (5) construction of a torula yeast plant twice the size of the Rhinelander plant to process their sulfite waste liquor. Apparently this fodder yeast process is practical and profitable.

The Evaporation-Incineration Problem

In the recovery of kraft cooking liquors the black liquor is concentrated in multiple-effect evaporators to about 65 per cent solids and then sprayed into a recovery furnace, which generates process steam and recovers the chemicals as a molten mass. It is natural that such means have been studied by the sulfite mills. But because of serious corrosion problems and the troublesome scaling of heat

exchanger surfaces by calcium sulfite liquors, the sulfite evaporator problem has been inextricable until recently. The industry had to await technological developments within many industries. The answer appears to have been found in the Rosenblad reversible flow evaporator (4)(7).

The first installation of Rosenblad evaporators in North America was at the Rhinelander mill in 1952 for the purpose of evaporating the desugared sulfite waste liquor. These evaporators permit the operator to switch the steam and liquor from one side to the other of the heat exchanger surface, so that steam may soften and scour off any lime deposits before they have a chance to harden as scale. Recently a larger unit was installed at the Consolidated Water Power and Paper Company sulfite pulp mill at Appleton, Wis. (7). This plant is essentially five vapor bodies, two falling-film type heaters and two submerged-surface type heaters with counterflow between liquors and vapors. The heaters are interconnected with the five vapor bodies. The fifth body is necessary for alternating liquor and heating surface at intervals determined by the operations. Piping is constructed so that all pipes carrying liquor in one operation can carry condensate in the next operation, thereby flushing these lines to remove scale. The installation can handle all of the mill's supply of collected sulfite liquor of 13.3 per cent solids, which is concentrated to 60 per cent solids for either outside sales, fuel in the recovery boiler room, or to drum driers for outside sales.

The drying equipment at Rhinelander consists of two twin drums operating at 100-lb. steam pressure. Either the concentrated desugared liquor or the normal concentrated sulfite liquor can be dried in this manner.

With a practical method for concentrating calcium base sulfite waste liquor, the industry has intensified its efforts to dispose of the waste by burning in a furnace and the recovery of the heat values in suitable steam boilers. Under proper conditions such disposal can result in a substantial reduction of the fuel purchased by the mill for operational steam. These fuel savings must be evaluated against the added investment and increased operating costs for collecting, evaporating, and burning the waste liquor. The economics of disposal by burning vary with the percentage of the available liquor solids collected, the concentration of collected solids, the efficiency of the burning and heat recovery unit, and the cost of fuel and other local factors. Inspection of Figure 3, prepared by the Babcock and Wilcox Company (1), along with consideration of the foregoing factors, indicates the need for careful integration in order to obtain optimum economy in operation. In preparing Figure 3 the following assumptions were necessary:

1. Including chemicals, 2,580 lb. of total solids per ton of pulp are available at 100 per cent collection of the liquor in the digester.
2. Solids have 7,900 B.t.u. per pound heat value.
3. Concentration of liquor leaving the evaporator is 55 per cent solids.
4. Quintuple evaporators with steam economy ratio of 3.8 to 1 are used.
5. Boiler efficiency is 65 per cent.
6. Steam is expressed on a from and at 212° F. basis.
7. Regular mill steam cost is 50¢ per 100 lb.

If it be assumed that collectable liquor of a certain mill is of 10 per cent solids concentration and amounts to 35 per cent of the total liquor solids leaving the digesters, the dotted line with arrows (Figure 3) indicates that 4,600 lb. of steam per ton of pulp will be generated, and boiler capacity equal to this amount must be provided. The net steam remaining after evaporation of the 10 per cent solids liquor to 55 per cent solids is 2,500 lb. per ton of pulp. The fuel saved then amounts to $1.25 per pulp ton, which must pay the

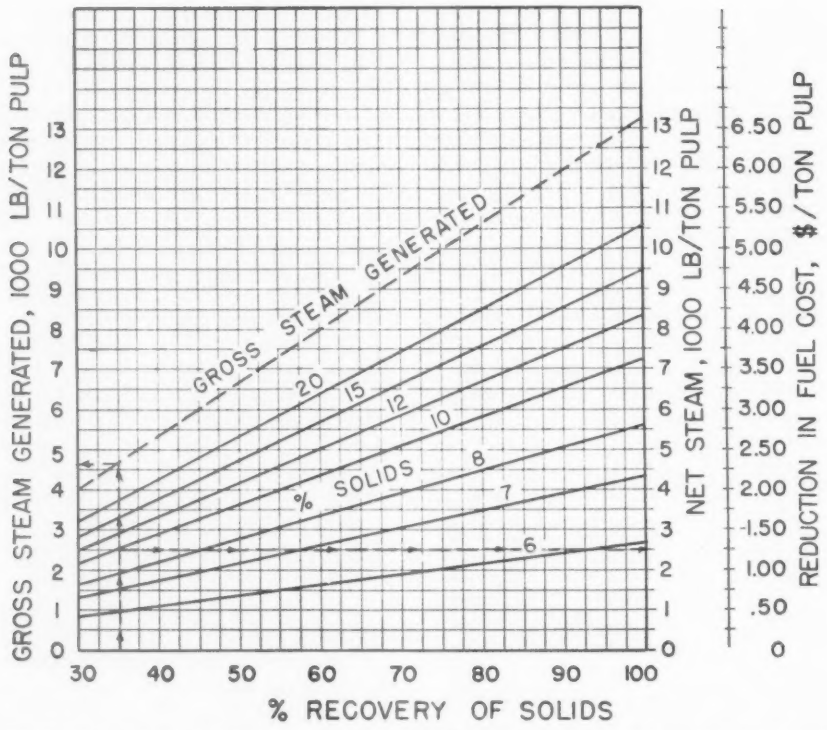
GROSS STEAM GENERATED, 1000 LB/TON PULP
NET STEAM, 1000 LB/TON PULP
REDUCTION IN FUEL COST, $/TON PULP
GROSS STEAM GENERATED
% SOLIDS
20
15
12
10
8
7
6
% RECOVERY OF SOLIDS
30 40 50 60 70 80 90 100
0 1 2 3 4 5 6 7 8 9 10 11 12 13
0 .50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50

FIGURE 3.—Estimated steam production for solids recovery from various concentrations of pulp solids.

operating costs and retire the investment for both evaporator and burning installations.

If it be assumed that the collectable liquor of the mill is only 6 per cent solids, but amounts to 70 per cent of the total liquor solids leaving the digesters, the gross steam generated will then be 9,200 lb. per ton of pulp. But because the evaporators must concentrate from 6 per cent to 55 per cent solids, the net steam remaining has dropped to 1,900 lb. per pulp ton, which results in a fuel saving of only $0.95 per pulp ton. Not only has savings been reduced because of low solids in the collected liquor, but also the investment is much greater since twice the boiler capacity and more than 3.5 times the evaporator capacity is required. It is important to note that if the foregoing 70 per cent of collected liquor was 10 per cent in concentration rather than 6 per cent, the fuel savings would be $2.70 per pulp ton, with a decided lower investment cost for evaporators and boiler installation.

Use of Other Metal Bases

If cooking chemicals could be recovered, in addition to recovering the heat value of the wood substances, the economics of the sulfite process would be improved considerably. The kraft process realizes such benefits. In the sulfite process, however, it is necessary to replace calcium bisulfite with either magnesium, sodium, or amonium bisulfite, since these bases offer a more economical recovery in spite of the more expensive metal radical. It is in this category that ingenuity of a high

order has already shown remarkable success. Reference already has been made to the magnesium base studies. A few years ago Weyerhaeuser Timber Co. converted the 275-ton calcium sulfite base mill at Longview, Wash., to magnesium base cooking. The development required a large capital investment. However, using this magnesium base the total chemical make-up is now approximately 25 lb. of MgO and 85 lb. of sulfur per pulp ton, as compared with 350 lb. of limestone and 270 lb. of sulfur per pulp ton when the mill was operating with calcium base cooking liquors. These chemical savings are estimated at $3.20 per pulp ton plus approximately $4.85 per pulp ton saving in fuel (8).

When sodium base liquors are burned the chemical solids are recovered from the furnace as a molten smelt identical to that obtained from burning kraft mill liquors. But the problem of converting sodium sulfide into sodium sulfite for re-use still awaits a practical solution. In those few mills where both sulfite and kraft processes are in operation the sulfite smelt can be used as make-up chemical in the kraft process.

Ammonia base cooking liquors are in use in several sulfite mills. Because ammonia decomposes from the heat of the chemical recovery furnace, burning methods are not applicable if the ammonia is to be recovered. However Crown Zellerbach Corporation at the Lebanon, Ore., sulfite mill, has found that by evaporating the ammonium base liquor to either 45 per cent solids or drying the concentrated liquor to a powder, a distinctly new substance is obtained chemically (2). It contains essentially 50 to 60 per cent ammonium lignin sulfonate, 25 to 30 per cent wood sugars, and 3.5 per cent nitrogen from the ammonia. As a dispersant, adhesive, reducing agent, leather tanning agent, and in the solidification of soils by forming complex compounds with chromium, this ammonium base sulfite waste liquor is reported to be far superior to similar calcium base liquors and has already demonstrated unique properties in new applications. In agriculture this ammonium lignin complex gives notable improvement in the physical properties of soils and serves as a plant stimulant. Extensive studies are in progress along such lines.

Possibly of even more importance are the condensation reactions that occur when this sulfite waste product is heated to elevated temperatures. The ammonia, lignin sulfonates, and sugars all appear to condense to larger molecular structures with different characteristics. This condensation occurs in either solution or dry form. The trend of the change is evidenced in solutions by increasing viscosity. Heating in closed vessels produces a stiff gel containing the original water. In the early stages these condensations remain soluble; with further heating they become insoluble, but swell in water. With more prolonged heating these substances become inactive with water. Many industrial applications are anticipated (2) for these modified ammonium sulfite lignin complexes.

Conclusions

There are two unyielding pressures which always bring about corrective action in stream pollution matters. The first, economics, is well exemplified by the kraft wood pulp industry. The other pressure is public opinion when implemented by governmental agencies. The sulfite wood pulp industry exemplifies this more disquieting source of pressure.

In the 1930's, when demand for better qualities in wood pulps became urgent, both the kraft and sulfite pulp mills met this economic problem by perfecting processing methods. The kraft industry was also able to enhance its economic gain by more efficient recovery of the cooking liquors. But the sulfite pulp industry found itself faced with an economic loss if waste sulfite liquors required processing.

Nevertheless, the two pulps were competitive and pollution was tolerated by governmental agencies.

In the 1940's it was necessary for the wood pulp industry to expand capacity substantially at a time when many other industries entered into competition for use of the nation's water resources. Because the kraft industry was fully integrated to control flagrant sources of stream pollution, all it had to do was tighten up on these methods for abating the nuisance and proceed with expansion plans. The sulfite pulp industry, on the other hand, could not take advantage of this outstanding opportunity to expand, for it feared the competitive advantages of the kraft mills and possessed no practical means for correcting stream pollution conditions.

Currently, however, the sulfite industry has a choice of methods which can relieve stream pollution. To use them requires burdensome capital investments and courage and determination in management. Canny evaluation of the future markets for wood pulp is essential. Utilization, rather than burning of spent pulping liquors, can change the economics of wood pulp manufacture decisively, for wood is composed of 25 per cent lignin. Each year the kraft industry in the United States burns 4,000,000 tons of lignin, whereas the sulfite industry disposes of 1,500,000 tons. Chemists are pondering the utilization problem. Some visualize lignin as a perpetual source of organic chemicals comparable to those processes producing chemicals from coal and natural gas.

Economic utilization of a waste, rather than mere disposal, will always be the eventual outcome of any waste substance. The lapse of time required for such conversion depends upon the intensity of effort and the skill of the scientists studying the problem. Eventually an economic process will be found to utilize lignin. Then the sulfite process may be the major beneficiary of research and find economical advantages in a by-product that will press the kraft pulping process to sustain existence.

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DISCUSSION

By H. W. Gehm

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An excellent review has been presented of the basic differences between the sulfite and kraft processes for manufacturing wood pulp, especially as these differences influence the problem of waste treatment and disposal in the respective segments of the pulp industry. The problem confronting

the sulfite pulping industry and the methods for the solution of the stream pollution problem that have been investigated and are being applied by the industry have been amply summarized. The solution of the sulfite industry's waste liquor disposal problem is indeed a difficult one and is a problem on which a tremendous amount of effort and money has been expended. It is likely that a greater effort has been made on the sulfite industry's waste disposal problem than on any other segment of the entire pulp and paper industry. It appears that the effort is now yielding some practical results, but a completely satisfactory solution has not yet been reached. Torula yeast and ethyl alcohol manufacture are nothing more than stop-gap measures at present and the burning and chemical recovery methods are still far from a satisfactory solution.

The writer is not wholly in accord with the author's conclusion that the lack of expansion in sulfite pulping, and the tremendous expansion in sulfate pulping, is directly attributable to problems of stream pollution in the former instance and lack of such problems in the latter. In spite of the fact that kraft pulping involves a fully integrated chemical recovery operation, the tremendous increase in capacity has created stream pollution problems. These problems have been created as a result of the following factors:

1. General upgrading of stream standards through public demand,
2. Large expansions in production involving the disposal of tremendous quantities of used process waters,
3. Hydrologic conditions encountered in areas where kraft pulping is located.

The last condition is of particular importance in the South, where the greatest concentration of kraft production is centered and where stream flows decrease drastically in the summer and fall, accompanied by increases in stream temperature.

It is true that the kraft industry has done much to alleviate its stream pollution problem by tightening up on its chemical recovery process; but that has not resulted in a complete solution of its problem. Tightening up on the chemical recovery has resulted in wastes of relatively low B.O.D. content which are free of toxic components. The large volumes of wastes encountered, however, still present an oxygen depletion problem in streams. Research and development work has shown that these wastes lend themselves to stabilization through biological oxidation. Generally, stabilization has been accomplished by means of lagoons.

Recently, however, research and pilot-plant studies have demonstrated that an accelerated biological oxidation process can be successfully applied to kraft mill effluents. Actually, the process is an adaptation of the activated sludge process and is capable of treating selected individual or mixed kraft mill effluents. The treated effluents are free from appreciable odor, free from substances potentially toxic to aquatic life, and lower in color than the untreated waste. It also was ascertained that effluents with temperatures up to 50° C. can be treated with no decrease in efficiency, and appreciable reductions in B.O.D. are consistently obtained. The major operating costs stem from the supplementation of the kraft effluent with the required nitrogen salts and compressed air for aeration. Construction costs are a major consideration, due to the size and quality of the structures and equipment required. Due to economic considerations, however, this type of treatment will probably be used primarily to augment the storage oxidation treatment method for kraft mill wastes.

Currently, the major problem with the disposal of kraft mill effluents is the matter of color removal. This is a problem which is directly attributable

to the general public demand for the upgrading of stream standards. The color removal problem is undergoing laboratory investigation. The major effort is being made on a process involving the treatment of the waste with hydrated lime followed by the separation of the calcium-organic sludge obtained. Recovery of the calcium in the sludge, which is an economic necessity, is accomplished by treating the sludge with solutions which contain sodium carbonate. The calcium is precipitated as the carbonate, the resulting supernatant containing dissolved organic matter and sodium compounds, which must also be recovered for economic reasons. Although this process appears somewhat complicated, its fits in well with the chemical recovery operations employed in manufacturing kraft pulp. Of the many color removal processes utilizing chemical treatment investigated to date, this process offers the greatest promise of success.

Expanding somewhat on the author's review of water and waste in the wood pulp industry, comment should be made on semi-chemical pulping processes and the pollution problems encountered therein. The semi-chemical pulping processes are achieving greater prominence each day due to the favorable competitive position of the semi-chemical pulps. This favorable position results from economies in manufacture, whereby the chemical costs are low and the spent cooking solutions are discarded along with the extracted wood substances. This is truly a manufacturing process in which the waste effluent treatment or disposal becomes enmeshed with the competitive aspects of the manufacturing process. Stream pollution problems in this case have served as an incentive to develop an economical chemical recovery system. These considerations are not involved when semi-chemical pulping is integrated with kraft production, because the spent chemicals can be recovered by incorporation into the kraft recovery system and re-used in the kraft pulping process.

In addition to the intensified effort being made in the development of a chemical recovery system, a great deal of effort has been made toward the development of waste treatment and disposal methods. Methods investigated to date have included submerged combustion evaporation, selective solvent concentration, with acetate recovery, and heat hydrolysis treatment. None of these methods has been the final answer, although some of the methods may be applicable under certain conditions. Chemical treatment of semi-chemical waste liquors has proved unsuccessful, as have some biological treatment methods, such as anaerobic digestion. Dilute wastes, in the range up to 1,000 p.p.m. B.O.D., lend themselves to biological oxidation using the method developed for kraft effluents. Although it is presently impractical to dilute the spent semi-chemical liquors to the aforementioned range, the biological oxidation process will be applicable to the residual wastes from semi-chemical pulping operations in the event that a satisfactory chemical recovery system is developed.

Stream Pollution

THE EQUITABLE USE OF STREAMS *

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As an introduction to this paper it is desirable to establish its ultimate purpose. A rational method is developed for allocating the absorptive power or capacity of a stream to assimilate pollution. Engineering judgment to determine the degree of treatment required cannot, however, be relegated to a secondary position. This thesis is offered, not as the ultimate method, but rather as the basis of discussion.

Philosophy of Stream Control

Those working in the field of pollution control are approaching unanimity in a recognition that streams and waterways are used for many purposes. It is quite generally accepted that all streams cannot be maintained in their state of pristine purity, and it is likewise generally accepted that it is improper to permit the degradation of a stream to a point below quality standards consistent with the expected use of the stream that can be attained within reasonable economic limits.

Uses of Streams

The purposes for which streams may be used have been well developed. Among the uses of a body of water may be included the following:

1. Potable water supply and domestic uses.
2. A source of protein food: namely, fish and shellfish.
3. Shipping.
4. Aquatic recreation.
5. Wildlife.
6. Water for agriculture and animals.
7. Raw material for industry.
8. Power.
9. Other industrial uses, such as cooling and condenser water.
10. Fire protection, street flushing, and other municipal uses.
11. Receipt of drainage water from swamps or other flooded lands.
12. Carriage of wastes.

It is recognized, therefore, that streams are used for many purposes and presently it is quite generally accepted that one of the proper uses for a stream or waterway is to carry away wastes. The uses at first glance appear incompatible; however, it is known from experience that a stream may indeed be used for many purposes providing there is judicial control and a recognition of the fundamentals of the Golden Rule. What, therefore, is the principle upon which one allocates rights and establishes obligations so that the most effective use of the stream may be obtained?

Classification

Clear differentiation should be made between stream classification and stream standards. By classification is meant an enunciation of the use that

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is expected to be made of the stream or a portion of the stream. Emphasis, for a moment, should be placed on the word "expected." If streams are classified on the basis of their present use, it could hardily be expected to improve stream conditions. Obviously, a great deal of judgment must be exercised in determining the expected use. It is customary, however, to hold public hearings before a stream is classified, thereby giving ample opportunity for all to be heard and to express their opinions concerning the reasonable use that is expected to be made of the stream following any reasonable exercise of control of pollution. Perhaps it might be preferable to use the term "desired" rather than "expected" use.

Stream standards, on the other hand, refer to the quality standards which the waters of the stream must attain in order to sustain the purpose for which the stream is classified. Standards are, in general, physical, chemical, bacteriological, biochemical, or other means of measuring the stream quality.

There are additional criteria for water pollution control which deal with the quality of the wastes to be discharged from a given plant, usually termed effluent standards. The effluent standards are exemplified by the standards of the State of Pennsylvania, of the Interstate Commission on the Delaware River Basin, of the Interstate Sanitation Commission, and others.

Effluent standards, which have some advocates, have the advantage of simplicity and definitiveness. In some areas they are well adapted; however, water quality standards are being generally adopted at the present time.

Stream Standards

Some of the established water standards are based on an effect or a potential effect, such as the Florida State Sanitary Code, which declares a menace to health is created "when acids, alkalis, or other chemicals or deleterious substances are discharged into waters so as to interfere with the biochemical functioning of the stream or waters, or where such wastes kill or interfere with the normal development of fish or other foods derived from waters." The Indiana Stream Pollution Control Board Regulation states: "Floating material including grease and oil shall not be discharged into any surface water in deleterious amounts or in amounts sufficient to affect injuriously fish life, fur-bearing or domestic animals, or the general biology of the water, or plant life in or in the vicinity of such water." On the other hand, the tentative water classification standards of the State of Maine provide definite numerical limits for dissolved oxygen, biochemical oxygen demand, pH, and *B. coli*. The Maryland Water Pollution Control Commission, in addition to the aforementioned criteria, has added numerical limits for fluorides, chlorides, phenolic compounds, iron and manganese, color, and turbidity. The New York State Water Pollution Control Board, in addition to some of the above, has numerical limits for ammonia and ammonium compounds, cyanide, ferro- or ferricyanide, copper, zinc, and cadmium. These are but a few examples.

What Next?

Here a break is made with tradition and the reader is asked to receive the remainder of these remarks with an open mind. To recapitulate: Present practice determines the use to which a stream is expected to be put, and as a result of that, indicates a definite classification for a part or for all of that stream. Following that, sufficient treatment must be given so that the established water quality standards for that particular classification shall not be violated. Here the question should be asked as to what degree of treatment is required to assure that the water quality standards are not vio-

lated. The usual approach is to require that the polluter determine the treatment facilities necessary to meet the established standards. It is usual that plans for such facilities must be submitted to a regulatory agency for approval. That agency, however, must take into consideration that this polluter is not the only one having rights to the capacity of that stream to assimilate pollution. A regulatory agency is usually reluctant to assign to any one polluter or any group of polluters the total capacity of the stream to assimilate the pollution load that remains in the effluent.

Regulatory authorities have not yet adopted a formula for determining how much of the assets of a stream shall be allocated to a single contributor. It does not appear equitable to permit a single municipality or a single industry to usurp the entire capacity of a stream to assimilate pollution, even though in doing so the stream is not despoiled to a point below the established standard for that stream. Certainly a future contributor—in the sense of time, not location—has certain rights to use that stream. A downstream occupant has rights to the waters of a stream, even though he may not exercise those rights for years to come.

Common law conceives that riparian rights provide for the reasonable use of a stream by the downstream owner. A definition of "reasonable" has long plagued jurists and it has been bracketed between the concept of "without material change in either quantity or quality" to the other extreme, which holds that wastes from some regional industry, such as the mine wastes in Pennsylvania or industrial wastes for which no reasonable methods of treatment have been evolved, may be discharged into the stream regardless of the damage to the stream and the downstream owners.

The allocation of the entire assimilating capacity of a stream has been advocated. Under such a proposal the assimilating capacity of the stream is reallocated as each new contributor is about to add to the pollution load. Regulatory authorities have been reluctant to accept this thesis with its consequent possibility of requiring an increased degree of treatment from plants only recently placed in operation.

River regulation, which includes the regulation and control of stream flow as well as pollution, has been effective on the Androscoggin River in Maine. To be successful it appears that the regulatory authority must not only possess outstanding technical competence and integrity, but also must enjoy the respect and confidence of everyone on the river basin. Under such conditions it may be possible to use practically all of the assimilating capacity of the stream with little or no reserve for contingencies or for new sources of pollution.

The water pollution control authorities often determine, on the basis of their best judgment, the reasonable amount of the stream's capacity to accept pollution that shall be allocated to a particular contributor. Should an upstream contributor be permitted to reduce the stream's capacity to accept pollution to a point close to the established standard, the law may not be violated; however, the immediate downstream contributor is deprived of the same rights as his upstream neighbor. As a result, the upstream contributor may be required to afford little or no treatment, whereas his downstream neighbor must afford a high degree because the stream has no further capacity to accept any waste without violating the established standard. The control authority frequently uses its judgment and indicates the degree of treatment that should be given to be equitable, and to reserve for further contributors yet to come some part of the stream's capacity to carry away wastes.

The control authority will usually wish to provide a factor of safety for unknowns, unexpected peak loads, or, perhaps, unusual droughts. The approving agency, therefore, must use considerable engineering judgment to determine the adequacy of the facilities proposed.

Some of the factors which go into the safety margin are as follows:

1. The critical stream flow.
2. The unexpected peak contributions.
3. A reserve assimilating capacity for future contributors.

Consider the first of the three items: namely, the critical stream flow. There is hardly justification for considering the worst conditions that ever occur. This is recognized as a subject which has long been within the purview of pollution control authorities. Frequency of both minimum and flood flows has been used as an argument in many engineering projects. When considering the amount of dilution required or the speed with which the stream will carry biochemical oxygen demand to a critical area, it is recognized that these can be computed on the basis of how frequently one is willing to accept unsatisfactory conditions. Is it now unrealistic to say that design should be for conditions which may occur only once in 500 or 1,000 years? Just as when storm drains are designed with a knowledge that they may be surcharged periodically, engineering judgment is used to provide that a sparsely developed residential area is designed for an occasional surcharge, whereas the frequency of surcharge in the densely developed business and warehouse areas where damaged stock stored in cellars or other potential losses warrants design for but infrequent surcharge. Accordingly, can not the dilution factor be approached in the same manner and, after study of the stream flow characteristics, the frequency be determined of violation of acceptable dilution or nuisance? These factors can be reduced to numbers and and a plea is made for the full use of all of the known tools on which to base engineering judgment.

Accordingly, it will be well to evaluate the damage in these critical periods. If a highly industrialized stream is being considered in an area used exclusively for industry, might it not be possible to accept a condition of zero dissolved oxygen that might occur on occasion—say, for example, once in 20 years. The conservationists unquestionably will object to a fish kill even once in 20 years; however, consideration must be given to a balance of economies on the one hand and the benefits derived on the other. If designs are made on the basis of the worse conditions that may occur once in 100 or 500 years, the public as a whole may be committed to impractical expenditures. It will always be a nice question as to the frequency with which one is willing to accept these unsatisfactory conditions, but it is a matter that should be faced with open eyes.

The second item is extremely difficult to evaluate. The character of the potential pollutant and the resultant economic loss when an unexpected peak load occurs, must be weighed. The possibility of placing the responsibility for damages should also be considered.

Referring to the third item: namely, the reserve capacity for future contributors. This has been one of the most difficult factors to establish. However, the time is approaching when this factor can be attacked in a rational manner.

Many are convinced that the full capacity of a stream cannot properly be usurped by any single contributor or group of contributors. The first consideration will be to make some reasonable determination of the percentage of the stream's capacity to assimilate a particular type of pollu-

tion, which should be reserved for future contributors. Undoubtedly, the type of stream, the type of development along the stream, the uses to which the stream is being put, the density of development, the proximity to other areas, the expectations for the future of each of these factors, and the confluence of other streams, all influence the determination of the percentage of the stream's ability to assimilate, which should be reserved.

No suggestion is made as to the numerical amount of the stream's capacity to assimilate pollution that shall be reserved for future contributors. Some feel that 40 per cent is far too high and that the reserve should be only 20 or 10 or 5 per cent. This is a determination that requires considerable study of the factors just enumerated. For the moment, however, let it be assumed for the sake of this dissertation that 40 per cent of a stream's capacity to assimilate a type of pollution, say oxygen demand, will be reserved for future contributors and 60 per cent will be allocated to the present contributors. What will be done when the next contributor approaches? It is suggested that the next contributor be required to install treatment works of such nature that his plant will draw upon the reserve capacity only to the extent of 60 per cent of the amount of the reserve capacity available: namely, 60 per cent of 40 per cent, or 24 per cent of the original capacity to assimilate that which he may discharge, leaving a residual available to future contributors of 40–24 per cent, or 16 per cent of the original capacity. The third contributor would have at his disposal 60 per cent of the remaining 16 per cent, or 9.6 per cent, leaving a balance of 6.4 per cent to future contributors. This is recognizable, of course, as the familiar law of reactions that are directly proportional to the amount of primary material involved. In the field of physics, this first-order reaction or logarithmic progress is evident in the decay of radioactive materials. In the field of pollution control, it is recognized as the form of Phelps' Law on the rate of biochemical oxidation. This first-order reaction is evident to all in pollution control work and is encountered frequently.

This first step leaves an apparent inequality, which requires adjustment. The contributors locating on the stream at a later date may have less stream capacity at their disposal. It is suggested that the approvals or permits be issued for a period of time equal to the useful life of the installation, in addition to the usual limitations of quantity or quality of the effluent. No better way is known of fixing the useful life than by using the period during which its cost is to be amortized. The bonds on municipal treatment works are issued for a period of 20 or 30 years depending upon the state laws, whereas industrial installations are governed by the amortization rate allowed by the Bureau of Internal Revenue for income tax purposes. Three bills have recently been introduced in the House of Representatives to encourage the prevention of water pollution by allowing amounts paid for industrial waste treatment works to be amortized at an accelerated rate for income tax purposes. Each of these bills permits amortization over a period of 60 months or 5 years. It should not be difficult to establish the reasonable useful life of a treatment plant. At the expiration of the permit or approval, the contributor would be called upon to make such additions or modifications in its treatment plant as will restore the stream to the standard of purity first established, which in this hypothetical case was 60 per cent of the stream's capacity to assimiliate a particular type of pollutant.

By this method, an industry proposing to establish a plant on a particular stream would have foreknowledge of the requirements both present and fu-

ture. It would have knowledge that it must be prepared to install additions, if necessary, at a pre-established time. Thus, there would be a rotating procedure that would assure the maintenance of a reasonable water quality irrespective of the number of contributors, always making allowance for and providing reasonable assimilating capacity for new industries and for a safety factor. The economic balance of the cost of high degree of treatment will function to prevent over-development of a stream.

The percentage of the available capacity of a stream to be initially allocated to existing contributors establishes a sort of parity to be maintained following the expiration of each permit. It will require sound engineering judgment in the establishment of this percentage or so-called parity. It may be possible that future thought, study, and new scientific data will permit fixing this percentage by some rational method. There need not be any deterrent, however, to accepting this method because it demands engineering judgment on the part rather than on the larger sphere of the problem. The adoption of this principle would more definitely place contributors on notice regarding the possible need of modifications and improvements to their plants at the expiration of their permits.

This method may be used whether the standards fix water qualities or establish quantitative limits; for, notwithstanding the fact that only a qualitative standard is established, the approving agency must within the confines of its own department have some idea of the quantitative limit necessary to meet the qualitative standards to determine the acceptability of the applicant's proposed treatment works.

Many engineers designed structures before Hardy Cross developed his methods of moment distribution, and many analyzed the flow of water in distribution systems before Hardy Cross developed his methods in that field.

Hardy Cross has said: "Engineering has, in most of its branches, been thinking out all of its problems again. This is not an indication that the laws of geometry or statics have changed. . . . However, new materials and new uses of old materials have been tried; new methods of using old principles have been invented. In nearly every field of engineering now there is a seething activity of invention, investigation, and re-investigation."

In the field of pollution control, there also must be alertness to improved methods of analyzing the problems.

OPERATION AND REPAIR OF WATER FACILITIES IN CIVIL DEFENSE EMERGENCIES

Technical Manual 13-2, entitled "Operation and Repair of Water Facilities in Civil Defense Emergencies," has been issued by the Federal Civil Defense Administration. Although intended as a guide to those concerned with water facility administration and operation, the manual has much of interest and use for those concerned with sewage utilities.

Among the generally applicable sections are those concerning possible forms of enemy attack and methods of minimizing the effects of enemy action. Also of general usefulness are the sections dealing with the preattack survey and operational plan, means of emergency communication, storage of emergency supplies and equipment, postattack operation, cooperation with other services, repair of facilities following attack, and test exercises simulating assumed civil defense emergencies.

Part II of the manual deals with the health aspects of water supplies, especially as concerned with detection of contamination and emergency decontamination measures.

The manual may be obtained for $0.25 per copy from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

METALLIZING EXPERIENCE AT TWO IOWA PLANTS *

I. Marshalltown, Iowa

BY L. F. SKORCZESKI

Superintendent, Sewage Treatment Plant, Marshalltown, Iowa

Metallizing, or metal spraying is not a new process, but was introduced in Europe about 1910, and in the United States about 1920. It was used primarily as a means of protecting surfaces against various types of corrosion, and to some extent as a means of decorating base materials. Up to 1930 the development of the process was comparatively slow; since then its use has expanded into every branch of industry in one way or another. This latter has come about as a result of the self-feed air turbine, which makes the process portable.

The process of metallizing consists of spraying the melted metal on a prepared surface. This is done by means of a special sprayer or "gun," which melts the metal and blows it on the surface to be processed. Today the main purposes of metallizing are to protect surfaces and to build up worn surfaces Both of these are accomplished with the same equipment, except that when a worn surface is worked on it is necessary to finish it to exact size by means of cutting or grinding.

Surface Preparation

The surface to be metallized must be thoroughly cleaned and roughened, so that the metal is shiny, dry, and rough, in order to have the sprayed metal bond itself to the original. If the new surface is properly bonded there will be no peeling or breaking away. On large flat or irregular surfaces this is accomplished by sand or grit blasting, using only the sharp abrasive. On shafts or other cylindrical pieces the surface is prepared by rough threading, cutting with a narrow lathe tool, or sandblasting. Another method of surface preparation is the electric bonding method, especially useful in the preparation of heat-treated or prehardened surfaces.

Equipment

A certain amount of special or extra equipment is needed. Sandblasting equipment consists of air compressor, sand blasting generator, hose for conducting the sand under pressure, and protective clothing. The protective clothing consists of apron, gloves, and face mask with goggles and respirator.

The spraying of the metal coating is done by means of a metal spraying tool generally called a "gun." This is a small, lightweight device consisting of a power unit and combustion unit united as an assembly. The power unit is a high-speed air turbine attached to a gear reduction; late-model guns are equipped with an electric power unit. Connected to the reduction gearing are

* Presented at 1953 Annual Meeting, Iowa Sewage Works Assn.; Ames, Iowa, Sept. 2–4, 1953.

the feed rolls, which feed the wire or rod through the unit during the spraying operation. The combustion unit consists of the flame nozzle and air tip. During the spraying operation the wire or rod is fed through the power unit at a uniform speed and on through the oxy-acetylene or oxy-propane flame, where it is reduced to a molten state. As fast as the metal is melted it is atomized and blown against the prepared surface. Here is it driven into any crevices, thus giving a coating of sprayed metal.

The metal comes in the form of a wire, usually ⅛ in. in diameter, or in the form of a rod, and is sold by weight. About $0.40 or $0.50 per pound is a common price, depending on the metal. For surface protection the most commonly used metals are zinc, aluminum, and a combination of zinc and aluminum. For building up worn surfaces steel and combinations of steel, depending on the desired hardness, are used.

Plant Experience

The Marshalltown sewage treatment plant was put into operation in 1940. After five years it was noted that some of the underwater units, such as air pipes and diffuser assemblies in the aeration tanks, were badly corroded or pitted. Some of the pits or indentations were about ⅛ in. deep, and in another few years would have been completely through. It was then decided to apply some sort of protective coating to prolong their life for as long as possible. All the iron pipe and fittings were prepared and metallized in 1946. Since that time further corrosion or pitting has not been noticed. The cost on this job, for materials alone, was about $0.22 to $0.23 per square foot. In this case the sand and wire had been purchased in small lots and the end cost was somewhat higher than if they had been acquired in larger amounts.

The next units to be metallized were the final clarifiers. The parts here consisted of weirs, troughs, and sludge removal mechanism. This was done in 1946 and 1947. By the summer of 1953 there was no evidence of further corrosion, although the clarifiers were in as bad shape as the aeration tanks. The cost on this job was $0.175 per square foot, exclusive of labor. The time spent on each tank was 12 to 15 days. The weir plates had to be removed, a scaffold had to be used, and a lot of the work was on pipes, shafts, and small pieces. The preparation took up most of the time, but if the surfaces had been painted the same amount of time would have been required for good preparation of the surface.

Most of the work had been done outdoors, both as to preparation and spraying. At one time it was decided to do the sand blasting indoors. This created a serious dust problem: an air mask had to be worn and the visibility was extremely poor. If any sand blasting is to be done indoors special rooms and equipment should be used.

The bar screen in the influent channel had to be replaced some years ago. Before placing the new one in position it was prepared and metallized with a zinc coating. It has been in service for more than six years and still is in very good condition, showing no signs of corrosion.

Another unit that was metallized before being put into service was the new mechanism in the flocculators, including the shafts and paddle arms. These parts were prepared and metallized as soon as received. This was a much easier job to work on than the others, because the sand blasting work required much less time and it was not necessary to go over it again to clean pits or depressions. The original equipment had been in service about six years and the shafts and arms were badly corroded.

The only experience with building up of worn surfaces has been on the pistons of a sludge pump. In this kind of wear the two ends of the piston are not worn at all, but the middle section, where the metal rubs against the

packing, wears down. At this stage of the life of the piston it is impossible to have the packing tight enough to get proper performance from the pump. Some time ago new pistons were put in the pump and it was decided to have the old set refinished. This was the first job of this kind done by this particular shop, and they almost backed out at the last minute. A rough cut of about ¼ in. was made along most of the piece. This was then sprayed with the metal until it was slightly oversize. The entire piece was then finished to proper size. The sprayed on metal seems to be well-bonded, and because of extra hardness should outlast a new set.

The big question is: "Was it practical to have this job refinished?" It is not positively known what a new set of pistons would cost at present, although by comparison with other things it would be more than $100—and that is what the refinishing job cost. The area refinished was 282 sq. in. on each piston at a depth of ¼ in. It is realized that the cost was high, but several things must be considered. This was a new thing for this shop and perhaps more time was spent on the first one than will be necessary on future jobs of this kind. Also, if it had been possible to take the parts out of service sooner, much less time would have been spent in the preparation and spraying, and less material would have been used. It is felt that the refinished pistons will give the same service as new ones. There are many times when a piece of equipment goes bad and it would take months to get a new part. It certainly is nice to be able to have that part refinished and back in service in a day or so, regardless of the cost.

On all of the units mentioned, even though the cost of metallizing ran somewhat high, there has been no further trouble from corrosion. On this point alone the work that has been done has proved worthwhile. It takes much more time than other methods, but pays off in the long run by giving years of trouble free service.

II. Fort Dodge, Iowa

By D. D. Douglas

Superintendent, Sewage Treatment Plant, Fort Dodge, Iowa

Metallizing is an economical means of preserving almost every type of equipment around a sewage treatment plant. Moreover, the health hazards in applying the coating are negligible when the operator understands his work and proper precautions are taken. Therefore, if the following discussion seems to paint a discouraging picture it should be remembered that all the hazards involved are being pointed out in order to aid any who might be considering metallizing to avoid costly mistakes. Actually, the process is no more dangerous than a great many other types of mechanical work the sewage plant operator is required to do.

First, consider cost. What is the most economical way to operate a certain unit? Sometimes replacement would be cheaper than metallizing. Such a condition was not in Fort Dodge when an attempt was made to metallize a digester roof.

To explain this statement it is necessary to review some of the processes involved in metallizing. First, sand blasting is essential, even on new metal, because when the molten metal is shot onto a smooth surface it is inclined to slip and does not form a solid contact. Therefore, the surface must be roughened so that it holds the metal. Secondly, metallizing must be done immediately after the sand blasting.

The necessary equipment includes an air compressor, an air control unit with filters and regulator, an oxygen

and acetylene gas control unit, oxygen and gas pressure regulators, gas flow meter, and wire control regulator. Obviously, to install a portable enclosed scaffold of sufficient strength to do a job of this kind is quite expensive. Also, in the process protection for the operators is imperative, as metal poison enters the picture and exhaust and suction fans must be used, together with fresh air masks.

Costs on this job are not known. However, it is estimated that it would cost approximately $16,000 to replace the digester roof and undoubtedly a great deal more than this was spent in the attempt to metallize it.

Therefore, it has been concluded that for this or any similar job the proper procedure would be to keep the metal protected, with paint or grease, and when replacement becomes necessary, to metallize the new sections before erection. This is being done by some highway departments and railroads on bridge work where a sulfuric acid condition exists. Predictions are for from 20 to 50 years of anti-corrosion resistance.

Also entering into the cost picture is the fact that the parent metal must be kept absolutely free of foreign matter. This is hard to do in some cases, due to the sweating of the parent metal. If moisture is present a poor bond—or no bond—will result.

Occupational Diseases Involved

As previously mentioned, the effect of metal spraying on health is negligible if proper precautions are observed. The common metals used are zinc, tin, lead, aluminum, copper, iron, nickel, brass, and bronze.

Lead Poisoning

Of these, lead is the chief hazard to health, and every possible precaution should be taken. Lead when taken internally can be expelled only by coughing or by the body fluids. It settles in and around the body bone structure and destroys the cartilage and tissue. Large quantities of milk are always given to combat lead poisoning.

The earliest sign of lead poisoning is the development of lead anemia, in which the complexion loses its healthy color and there is a shortness of breath. Anyone working with the process of spraying lead should be examined every two or three weeks by a physician. Each person working with lead should consume from a pint to a quart of milk a day as a precautionary measure.

The later or advanced symptoms of lead poisoning are increased anemia, constipation, abdominal pain, and muscular weakness. No eating or smoking should be permitted near this work.

Metal Fume Fever

When the Fort Dodge digester roof was sprayed every person working on the job was sick, including the sand blasters as well as the metallizers. It is believed that most of the workers had metal fume fever. One of the workers doing the metallizing called a doctor one night. He diagnosed the condition as lead poisoning. The peculiar thing about this was that zinc wire was being used and a test for lead was negative. Also, the manufacturer of the wire claimed that there could not possibly have been any lead in it. However, the hospital laboratory chemist who ran the diagnostic tests insisted it was lead poisoning.

Cadmium and tin are extremely irritating to the nose, throat and eyes and will cause severe vomiting. Spraying of these metals should never be attempted without a suction and exhaust fan. Metal fume fever and pneumonia also can result from these metals, so a satisfactory fresh air mask should be used with them.

Metal fume fever is not considered serious, but it is extremely uncomfortable. Its chief results are alternat-

ing high fever and chills. Extreme cases have resulted in pneumonia. It can be prevented only by improved ventilation.

Silicosis

Sand blasting is by far the most serious risk metal sprayers are exposed to. The result may be silicosis. It has been shown that of the number employed, sand blasters are more apt to suffer from silicosis than any other group of workers.

Silicosis is a degenerative disease of the lung tissue in which extensive scarring occurs. Its presence in early stages can be detected by x-ray, although it usually takes 7 to 10 years to develop. In later stages it is frequently complicated by tuberculosis brought on by the degeneration of the lung tissue.

As the name implies, silicosis is brought on by the inhaling of small particles of dirt, sand, iron oxide, etc. The dust which can be seen by the naked eye is far less dangerous than the millions of particles too small to be seen. The main points which must receive careful attention if sand blasters are to avoid silicosis are as follows:

1. Substitution of automatic blasting for hand blasting whenever possible.

2. Provision of the most modern and efficient sand blasting plant. A discussion of sand blasting plant and appliances is beyond the scope of this paper; however, too great emphasis cannot be placed on the selection of this equipment.

3. Care in the choice of personel. The sand blaster should be an intelligent, responsible person who understands his work and its hazards and is free of any signs of tuberculosis.

4. Wherever possible, steel shot should be substituted for sand.

General Precautions

It is wise to keep a close watch on personnel that are metallizing. All reasonable precautions should be taken to keep metal particles from the air. Lead spraying should be done only under strictly guarded conditions. Of course, there is always the possibility of explosion or fire in case of a gas leak.

Despite the seeming multitude of hazards and limitations surrounding the use of metallizing as a maintenance and repair process, it is re-emphasized that metallizing is economically justified for all work around a sewage plant except where the cost is greater than the replacement cost. In that case, one is even justified in investigating the economics of metallizing the replacement parts before installation, not only as a means of reducing corrosion, but also as a preventive measure against having to later disassemble the unit or metallize it in place.

DISPOSAL OF WET DIGESTED SLUDGE AT MARSHALL, MISSOURI *

By Henry Hayob

Superintendent, Sewage Treatment Plant, Marshall, Mo.

Drying and disposal of sludge is one of the major problems of a sewage treatment plant, constituting a headache for those who operate them, especially during a rainy season with few sunshiny days, little wind, and numerous other elements which enter into drying of sludge. One of the elements at Marshall's two treatment

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plants was the design of the drying beds, which permitted very little wind action on them.

The beds at the Northeast plant are 50 ft. wide by 100 ft. long, divided into eight sections. With the proper amount of sand on the beds, the top of the sand is 34 in. below the top of the walls. Therefore, there is little wind effect on the beds. The pipes for the discharge of the sludge to these beds are anchored to the center wall, so the sludge can be discharged into beds on either side. It is impossible to get a truck into the beds so as to fork the sludge into it. Consequently, the sludge must be forked out of the beds, then loaded into a truck to be hauled away.

The accumulation of the sludge that forked out of the beds makes an ideal place for insects to breed. These and other factors—such as the cost of labor and the short time during which the sludge dries out quickly also being the busy months otherwise—resulted in a decision to spread the sludge wet on farming land. This procedure has been followed two and one-half years, at times of our own choosing during any season of the year.

For disposal of the wet sludge, a 2-ton truck (Figure 1) equipped with a 4-yard dump bed and two-speed axle was purchased. The dump bed is essential for washing out the tank; also, for spreading the sludge evenly on the land. The cost of this unit was as follows:

Truck	$2,077.00
2-speed axle	166.10
Extra (dual) tires	130.00
Dump body with hoist	770.00
	$3,143.10
Tank, made by local shop	453.50
Total	$3,596.60

The tank is 74 in. wide, 50 in. high, and 100 in. long; or about 3½ in. nar-

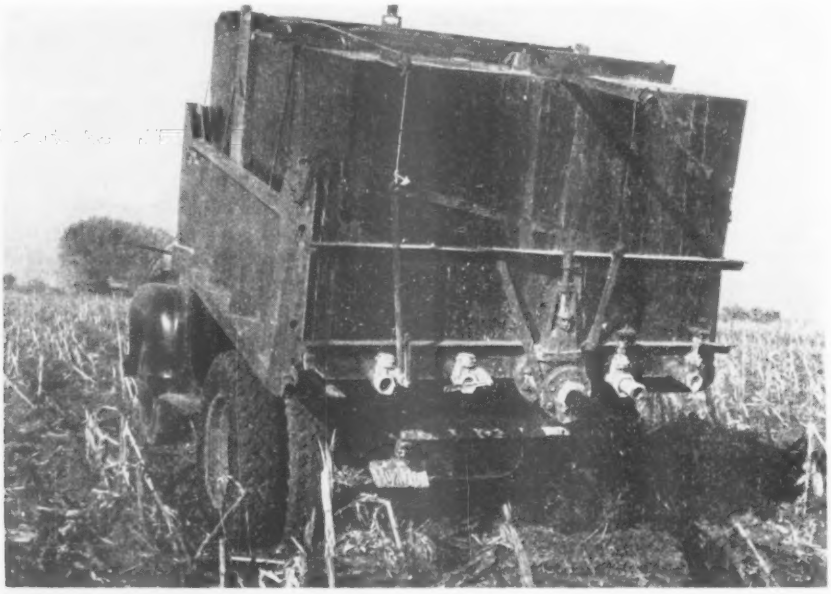

FIGURE 1.—Shop-made tank mounted in dump body has several quick-opening valves for spreading liquid sludge on farm land.

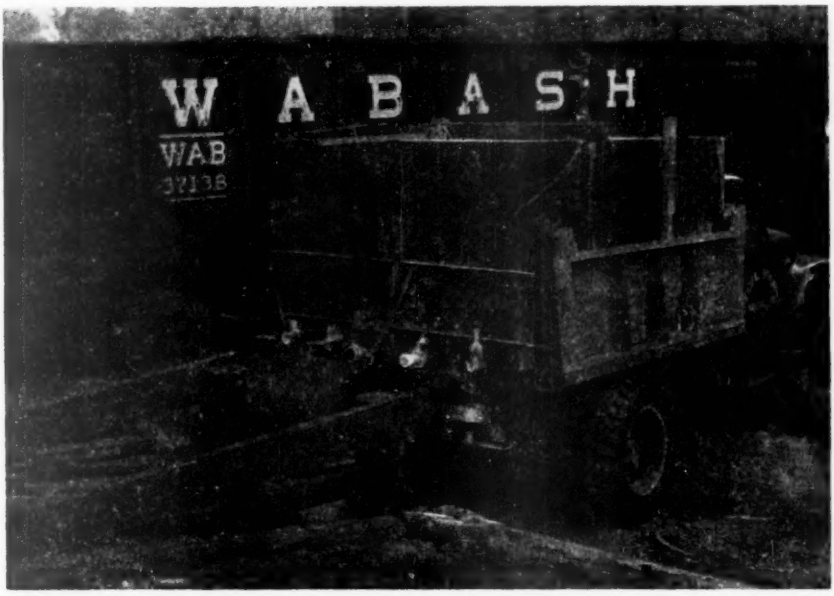

FIGURE 2.—Simple dock facilitates removal or loading of tank.

rower and 4 in. longer than the body. This tank can be loaded and clamped to the truck in 30 min. by two men, or unloaded in the same time for conversion back into a dump truck. The tank, made of 12-gauge iron, which is 7/64-in. thick, and the necessary angle-iron braces, weighs a total of 1,374 lb.

If another tank were to be made, 10-gauge iron would be used, but the height of the tank would be reduced to 45 in. This would reduce the tank capacity from 1,625 gal. to about 1,440 gal.

To unload the tank from the truck, an unloading dock (Figure 2) was built at the same height as the bottom of the tank when it is in the truck. To unload, the truck is backed up to the dock, the end of the tank extending back of the truck is lifted, and a 2-in. pipe roller is placed under the tank, which can then be easily pushed out of the truck. The roller is left under the tank so that it can be loaded in like manner. The tank has two 4-in. openings in the top for filling and venting, and four 2-in. and one 4-in. quick-opening discharge valves. The 4-in. valve is self-closing and can be opened or closed from the truck operator's seat.

This method of handling sludge has been a great help in the control of insects at the plant and a moral builder for labor. No consideration would be given to going back to the old method.

Many uses have been found for this tank truck besides sludge disposal. Among many other duties it is used to haul water to settle trenches, and a sprinkler has been attached for settling dust and packing streets when they are scarified. This piece of equipment is considered a "must" in the plant's operating equipment.

MAINTENANCE AND OPERATION OF PRIMARY TREATMENT UNITS *

By Frank H. Miller

Chief Engineer, Hampton Roads (Va.) Sanitation District Commission

By definition, maintenance is the holding or keeping in a state of efficiency and operation is the performance of work or acts to produce an effect. For all practicable purposes sewage treatment is an industry in which raw material is converted by sound engineering, chemical, and biological practice to products more nearly meeting the required needs. This industry must be operated, however, with little or no control over the quantity or quality of its raw material, but must still produce results or "consumer goods" which are both uniform and acceptable. The proficiency with which the facilities available can be maintained and operated will usually be the index of success in converting the unwanted raw material to one which will be acceptable to at least the majority of the industry's "market."

Plant and equipment design are so significant to the ability to maintain efficiency and secure required results that brief comment is warranted on some of these factors that it is felt have been important in connection with the primary treatment facilities in the Hampton Roads Sanitation District.

The District has now had in operation for approximately five years three primary treatment plants, the primary units of which are substantially the same and consist of four-tank settling basins operating in parallel, each of which is divided into two sections. Each section is equipped with separate chain-and-flight equipment and scum removal equipment; each tank or each two sections is equipped with cross collectors of either the chain-and-flight or helicoid type. The plants have a theoretical settling capacity adequate for approximately 10 m.g.d. at the Army Base in Norfolk, 22 m.g.d. at Lamberts Point in Norfolk, and 12 m.g.d. at the Boat Harbor plant in Newport News. Anticipating the question that practices in these plants may be different, due to size, from those of a smaller or a larger plant, it is doubted that there is any material difference in the basic maintenance and operation requirements for producing good results merely because of variation in size or number of units used.

Access to Channels

Design at one of the plants included an almost completely concrete slab covered rectangular influent channel supplying the four basins. The influent ports from this channel to the basins are equipped with shear gates, but the top of the ports is approximately 1.5 ft. below the normal flow line of the channel. It is, therefore, not accessible for either observation or cleaning. Scum tends to accumulate, particularly near the ends of the channel, to some extent restricting flow to the farthest removed basins. Experience prompts the caution that every influent channel be kept uncovered to the maximum extent consistent with good design and that under no conditions should the ports between this distribution channel and the basins restrict the free transmission of scum or other floating material between the two. That is, the flow line, like the floor line, should be entirely clear of ledges, baffles, or other obstructions. Experience also indicates that full-depth influent gates, preferably of aluminum

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with aluminum guides, more than justify their added cost in reduced cost of maintenance and operation. Gates of wood with iron strapping also are to be avoided wherever practicable.

Settling Basins

Unequal distribution between multiple settling basins served by a common influent channel can badly unbalance the loading to the respective basins. The most effective distribution seems to result where the flow is toward a wall constructed perpendicular to the flow direction, with distribution laterally from this point.

Access to all flumes and channels and to the side walls of sedimentation basins, and elimination of overhang on these operating walls, greatly simplifies normal maintenance and operation. There are, of course, limits to which this can be accomplished. But by judicious use of gratings and minor alterations in design, operating problems will be simplified by anything done toward this objective.

The plants also have several points at which hand rails could have been used in place of gratings. In some instances the substitute hand rails have been installed. Gratings should be used only where it is absolutely essential if they are over points from which samples must be taken. Experience with steel gratings has been most unsatisfactory. Many of those included in the original design are being replaced with gratings of a less corrosive material after only five years of use. As is well known, proper cleaning and painting of gratings is a nearly impossible task.

Sludge Collection Equipment

As regards mechanical sludge collection and cross collection equipment, there is a wide divergence of views. It is not desirable, however, to use any flight of greater than 6-in. depth. Also, helicoid rather than chain-and-flight-type cross collectors reduce maintenance and operation problems, split-type main drive sprockets are preferable to the solid type, and a square key and keyway-type of clutch on the drive mechanism is preferable to the saw-tooth type. Several manufacturers either will not or are reluctant to furnish flights deeper than 6 in. on the basis that a 6-in. flight is sufficient to handle any sludge loading within the tank, and no good is obtained from any additional depth. Deeper flights ride on their bottom leading edges and do not pass smoothly down the tank, but tend to advance in jerks or hops.

Objections to chain-and-flight-type cross collectors at the influent end of the basin are (a) there are many more moving parts, which increases the maintenance, and (b) usually they do not permit the use of a type of basin influent baffle that will prevent the flow from being diverted downward into the hopper, where it is likely to cause scouring of the accumulated sludge. Personal observation further indicates that the flights themselves result in greater agitation of the sludge than do the helicoid-type collectors.

Split Sprockets

Anyone who has had to replace a solid or one-piece drive shaft sprocket where the sprocket cannot be readily slipped off the end of a short shaft will recognize the advantage of the split-and-bolted type of sprocket. In the Hampton Roads plants, time of installation is reduced by use of the split type from an average of possibly 6 to 8 man-hours to less than one-fourth as long. The cost differential for the most common sprockets is only that between approximately $19 and $27. As a matter of information, considerable difficulty was experienced in finding a useable split-type sprocket, but they are now available for use on most makes of equipment. This does not mean that this type sprocket can always be purchased from the manufacturer of the equipment. If the re-

quired sprocket is carefully specified, however, there is no reason to go to the original manufacturer for replacement. This has the additional advantage of permitting competitive purchase and applies to a large majority of the other chain-and-flight equipment, as well as to the sprockets.

Clutches and Drives

Objection to sawtooth-type couplings on drive equipment is based largely on the high breakage rate experienced. The key-and-keyway type eliminated this difficulty to a great extent. Usually it is a slightly cheaper type of clutch and operation with it seems equally as satisfactory.

Another source of considerable trouble resulted from the direct coupling of a drive motor to the gearbox mechanism. For some reason, alignments were most difficult to maintain and failure of alignment resulted in breakage, motor troubles, and frequent repairs. In lieu of the original equipment several V-belt drive connections have been installed between motor and box. These have completely solved the problem.

Another design characteristic in one of the plants, which also has been seen in several others, is the use of a full-length wood partition between sections where a basin is separated into two parallel sections. The purpose, of course, is to prevent short circuiting or crossover of flow between the two sections. Two of the Hampton Roads plants do not have such a longitudinal baffle, yet no difference is observable between the plants in the efficiency of function. The basins are more easily operated and certainly more easily maintained if the baffles are not used.

Other Comments

Other comments regarding particular points of design that it is felt have affected maintenance and operation concern the provision of sludge wells and suitable telescoping valves in the well and the question of using relatively new and untried designs or types of equipment.

At the one Hampton Roads plant not equipped with a sludge well and telescoping valves, so that direct pumping from each basin is required, it is a continuous problem of training, retraining, and threatening to keep operators from either inadequately pumping sludge or, equally as bad, from over-pumping to the digesters. In spite of all the good theory as to control by taking regular samples from the sludge pump, experience indicates that in practice this method of sludge removal too frequently is the cause of either over- or under-pumping the basins.

The word of caution as to the untried stems from relatively few such conditions existing in the local plants. Nevertheless, as with practically every plant, some do exist. Generally it is preferable to have had the "gimmicks" given a thorough trial by somebody else and to use only proven designs.

Maintenance Standard

Probably the most difficult job faced by anyone is to secure and keep a continuously adequate maintenance standard. This applies equally to primary units as to some of the more complex equipment or functions. The difficulties at Hampton Roads were normal and to be expected, in that within a period of one year the Commission placed in operation its 3 treatment plants, some 30 pumping stations, and some 65 mi. of major interceptor sewers. There are in the system, just as one example, approximately 325 electric motors, totaling more than 2,400 hp.; also, more than 2.5 mi. of pintle chain is used, mostly in primary treatment units.

The Commission had no existing organization from which it could expand. The present operating personnel, now totaling about 70 employees, has been recruited, trained, and held

responsible for functions in which they had absolutely no experience, with one or two exceptions, just five years ago. Also, there has been a constant heavy personnel turnover due to the critical defense status of the Hampton Roads area and the fact that competitive employers had a virtually complete disregard for pay scales if they needed a man.

In addition, the entire Hampton Roads service area is extremely low and flat and is subject to relatively high temperatures day and night. Consequently, the sewer system contains numerous pumping stations, few sewers having more than absolute minimum grades, long force mains and siphon sewer lines, and sewage temperatures which have for periods of two or three weeks at a time run in the vicinity of 90°. The sewage is highly septic, hydrogen sulfide is produced, and corrosion of fixed structures and mechanical and electrical equipment is at a greatly increased rate.

The treatment plants are operated basically on a system that places one man in responsible charge of routine maintenance, including repairs and replacements of a minor nature, and lubrication. Major replacement or repair is the responsibility of a maintenance section, which is available for work in or outside of the treatment plants.

Maintenance Records

The employee responsible for routine maintenance in the plant is required to keep complete records on each piece of equipment and to accomplish his functions on a planned schedule, compliance being noted each time the function is performed. A system of 5-in. by 8-in. maintenance cards is used on primary treatment as well as other units.

The record system is generally modeled after the army system (1), although the basic system has been simplified in many ways. Two cards are kept on each unit of mechanical equipment. One is an equipment record; the other is an inspection and service record. The equipment record card has on the front complete data as to that unit. (For example, on a motor the serial number, style, frame, class, and any other available characteristics or nomenclature is noted.)

Such a card is made up for each motor, gearbox, chain assembly, etc. It is also valuable as a permanent record for needed replacements and helps greatly to assure that orders will be placed in proper form to avoid confusion on the part of the supplier as to what is needed. On the bottom and back of the card there is a space for entry of non-routine types of maintenance or checks.

For example, all motors are resistance tested with a "megger" at regular intervals by the electrician, who at the same time takes ampere readings and observes the condition of the motor. These data are noted. If winding resistance varies, indicating insulation failure, the motor is dried out or other checks are made to whatever extent is indicated. Likewise, an increase in ampere reading indicates excessive loading or similar difficulty and the cause is sought out and corrected before serious trouble occurs. At the time of the check a notation is made of the work done, including with it the date and the initials of the person in charge of the work.

The second card, covering routine inspection and service, includes on the front a summary of maintenance and lubrication requirements. For example, the front of the card might show (a) motor bearings—lub. each 6 months, (b) gearbox—change oil every three months, and (c) check gearbox oil each month. On the back of this card the plant maintenance man enters the work done, either by reference number to the function required on the front of the card, or by description, showing also the date of service and his initials.

The cards are separately classified as a guide to the work that needs to be performed. They furnish a permanent record, both as to maintenance accomplished and as to the maintenance requirements over a period of time, on equipment of various makes and types.

As an adjunct to maintenance of equipment, an extensive effort has been made to secure manufacturer's shop and section drawings of each piece of equipment so that data are available as a guide to the proper disassembly or reassembly of equipment and as a further check on the exact type or number of parts for ordering purposes. During the past two years operation has been taken over of a few installations including relatively old equipment where this information is not available. Inability to obtain the information in several instances has resulted in delay of work on the equipment and in obtaining incorrect replacement parts when they were needed. As a result of this experience, it is deemed most essential to accumulate this information while equipment is relatively new and standard and the information regarding it is available from the manufacturer. It might be added that the manufacturers of equipment in the District's plants, and this includes possibly 200 or more, have been most cooperative in furnishing the information. In most instances they were more than glad to do so, as it permits them to render prompter and more efficient service.

Outage Tags

Despite moderate criticism of the "gimmicks" that designers and manufacturers have given the plants the doubtful privilege of trying out, there probably are as many of "home" conception as are likely to be found anywhere, including automatic proportioning samplers, automatic chain oilers, and several others.

One of the most valuable of these of a simpler type is a bright yellow shipping tag, for which a rubber stamp was made with letters about ¾-in. high saying "DANGER—DO NOT OPERATE." There is sufficient space on the card for notes as to the reason and who said so. This card has a string attached and whenever any piece of equipment is found—by the electrician, maintenance foreman, or anyone else—to be in a dangerous condition or otherwise unsuitable for operation until some change or repair is made, the tag is hung conspicuously on the equipment or on its controls.

This simple bright yellow tag has made a material difference in the degree of trouble encountered and has been responsible for saving several pieces of equipment that might otherwise have suffered major damage. Particularly, as at Hampton Roads, where a relatively large number of people have some duty to perform in connection with separated units of the operations, there was a strong tendency to let the equipment go when first signs of trouble were noted, or not to pass on the word to others who would be interested. Use of the card seems to encourage taking equipment out of operation when it is in a doubtful status and in keeping it out of operation until it is adequately checked out for use.

Personnel Problems

Routine operation of primary treatment units is more closely related to personnel and the usual personnel factors than to any other single influence. If it were possible to keep the same group of operators in the plants for an average of at least four or five years, the costs, treatment efficiency, and maintenance would reflect a degree of improvement unlikely to be equalled by any other single factor. With the two-fold objective of, most important, just being sure of getting help and, second, of trying to keep present help for longer average periods, the plant operators' pay scales

have been increased between 1949 and 1953 from a range of $2,412 to $2,772 to a present range of $3,168 to $3,744 per year. Even with the current scale, turnover during the six-month period ending in May, 1953, in operators alone averaged 15 per cent. However, it is materially reduced from experience of early 1952, and the present improved pay scales offer more hope.

Basic Operation Factors

Basically, operation of primary treatment units involves only three principle functions: (a) prompt and effective removal of settled sludge, (b) removal of odor-producing scums from the tank, and (c) performance of necessary housecleaning and minor maintenance functions in a manner which will prevent unsightly conditions or fouling of the treatment units or the equipment integral to these units.

It is impossible to state the exact procedure that should be followed in the removal of sludge in a way that will apply to plants of different location, different loading, or slightly varied design. It may be interesting to review the Commission's pattern of operation, which is probably reasonably typical for the larger plants.

The plants are operated by three shifts of personnel. Each primary sedimentation unit is operated on a basis of five cycles daily, with one being scheduled on the night shift (midnight to 8:00 A.M.) and two each on the day shifts (8:00 A.M. to 4:00 P.M. and 4:00 P.M. to midnight. On each cycle the following procedure is followed:

The main flight mechanism is operated long enough to carry the flights once the full length of the basin; that is, if a flight is at the bottom effluent end of the basin the equipment is run long enough to bring this flight to the sludge hopper at the influent end. This requires approximately 1 hr. The cross collectors are started after the main flights are stopped, and remain in operation until sludge withdrawal is complete. This cannot be followed as an exact pattern where shallow sludge hoppers are used, as in the Boat Harbor plant, which is equipped with flight-type cross collectors. Here the storage is inadequate in the hopper and the cross collectors must be operated for a few minutes before the main flights are stopped, most of the sludge being pumped while both the main flights and the cross collectors are in operation. Sludge is withdrawn at as even a rate as is practicable to the sludge well, where one is available, or by direct pumpage at the minimum practicable rate where the well and telescoping valve is not available. Time of withdrawal using telescoping valves and sludge wells is variable from as little as 3 hr. per day total up to 16 or more hours; where sludge is pumped direct, from a minimum of about 6 to 11 or more hours per day.

The schedule of these operations can readily be adopted to local operating conditions, but these conditions must be studied, a schedule worked out in keeping with them, and operators must be alert to variations from the norm if one is to avoid sludge rising in the primary tanks due to inadequate removal, excessive wear on operating equipment due to over use by unnecessary operation, overloading of the digester by pumping of too much thin sludge or plain sewage, or breakage of flights and other equipment by excessive sludge accumulations.

There has in the past been a condition at Hampton Roads where the basins would load to a point where 25 to 30 per cent of their capacity was sludge of 4 to 10 per cent solids in spite of the fact that the scrapers were operated on a regular schedule and as regularly failed to obtain any sludge. It is thought that the condition was due to a rather unusual industrial waste reaching the plant. The point, how-

ever, is that when this sludge began to move it was completely out of the question to get the flights in motion until the tanks were drained down and the sludge flushed, or even shoveled, from the basins.

Unfortunately, however, one or two flights, or something worse, were usually broken before the equipment was completely blocked. In this connection, it is a good idea to watch the shear pins with an eagle eye and not let the operators substitute old bolts or rusty nails for the proper shear pins.

Adequate operation necessarily demands adequate operating records, including records of primary unit operation, which should show the amount of sludge pumped, any discrepancies from normal operation, and any special functions of housekeeping, parts replacement, etc., performed. Accumulation of such records is the only means by which an economical and effective pattern of operation can be established over a period of time.

Operational duties also include sampling in accordance with the established schedule and interpretation of observations, such as condition of sludge being withdrawn in a proper manner. As with most sewage treatment personnel, the plant operator's ability to understand the fundamentals of what he is doing and to reason logically as to the effect which his procedures will have on the over-all operation is the most important single factor in the results to be obtained. Of our three shifts each day, two are covered in each of the three Hampton Roads plants by a single operator who is on duty with one laborer-helper. It is difficult to exercise supervision during these shifts and the only substitute for such supervision is the proper training of the operator and his full acceptance of the responsibility for carrying out his duties effectively.

As a matter of scheduling, most of the minor housekeeping functions, such as minor painting, grass mowing, and other duties of this type, are logged by the chief operator to be performed by the shift operator or his helper on either the evening or night shifts. In this way practically full utilization of the operator's time on duty is secured. Operational duties of a less routine nature are usually performed by the day operator and helper, or by the maintenance man or the chief operator, both of whom are normally scheduled for the day shift.

In conclusion, the structures and equipment for sewage treatment, exclusive of transmission facilities, represents at Hampton Roads an investment of approximately $30 per service unit connected to the system. This is a relatively low figure. Operating costs for both maintenance and operation of the three treatment plants is approximately $2.85 per unit served per year. Annual operating and maintenance cost is approximately 9 per cent of the slightly more than $3,000,000 capital cost initially spent on treatment facilities, at present being approximately $20 per million gallons treated. By any yardstick, the money spent on operation and maintenance is a small share of the capital investment in facilities which have been made available.

The maintenance and operation secured largely govern the effective life of the structures and equipment for which the capital was expended, and the degree to which it performs the functions for which it was intended. It is, therefore, imperative that the necessary money be made available as well as that it be spent wisely, in order to safeguard both the useful life and the effective use of the facilities being held in trust.

Reference

1. U. S. War Dept., "Inspections and Preventive Maintenance Services—Sewage Treatment Plants and Sewer Systems at Fixed Installations." War Dept. Tech. Man. 5–666, U. S. Govt. Printing Off., Washington, D. C. (Sept., 1945).

INTERESTING EXTRACTS FROM OPERATION REPORTS

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage and Industrial Wastes Associations, Room 325, Illinois Bldg., Champaign, Ill.

Twenty-First Annual Operation Report of the DeKalb (Ill.) Sanitary District Sewage Treatment Plant, for the Year 1952 *

By Donald E. Henn, *Manager*

General

The weather in 1952 was much more favorable to the operation of the sewage treatment plant than was the extremely wet year of 1951. The only serious trouble encountered was a sewer stoppage requiring the relaying of 48 ft. of sewer and construction of a new manhole at a 14-ft. depth.

No difficulty was experienced in handling canning wastes, due to the new waste handling units constructed at the canning plant in 1951.

Two fish kills occurred in the DeKalb branch of the Kishwaukee River, both due to cyanide traced to a city storm sewer.

Sewage flow during the year totaled 619.54 m.g., the second highest flow in the history of the plant. (The flow in 1951 had been 643.25 m.g., probably due to the extremely wet weather.) All of the flow was given complete treatment.

Plant Units

The stationary rack that catches the screenings as they are raked from the bar screen was replaced. Otherwise, this unit required only the usual maintenance attention. The grit basins required only the usual cleaning attention.

The influent and effluent channels of the primary settling tank were thoroughly cleaned in July, the tank remaining in service throughout the year. The sludge collection mechanism required only the usual maintenance attention of greasing and replacement of electrical contacts.

The trickling filters operated efficiently and without serious difficulty throughout the year. No evidence of rock spalling in the bed or clogging of underdrains developed and no ponding was experienced. The beds unloaded early in May and to a much lesser extent in the fall. Due to controlled waste flow from the canning plant during the canning season, the load on the filters during the critical summer months was greatly reduced. The lagooned wastes left from the 1951 pack were drained to the sewers in the spring; the filters took care of this load without trouble. Some lagooned waste from the 1952 pack was treated late in the fall without experiencing the difficulty with heavy, liver-like growth that developed in 1951.

The secondary settling tank is not used during the winter months when the filter slough is slight. It was put in service on May 6 and by-passed for the winter on December 1. On October 29, difficulty with the mechanism caused unwatering of the tank, which located 10 large vitrified clay building blocks and some smaller stones thrown into the tank by children.

* For last previous extract see This Journal, **24**, 10, 1313 (Oct., 1952).

Digester

No foaming occurred and the unit operated without serious difficulty throughout the year with one exception. Early in March considerable sludge was drawn at about the same time the spring thaw developed, increasing the sewage flow and reducing the sewage temperature. Reduced efficiency of the primary tank reduced the raw solids to the digester. With the low temperature condition and drawing of a large quantity of digested sludge just prior to the reduced feed, gas production dropped off from 12,000 cu. ft. per day to 2,970 cu. ft. per day. The drop in gas production only aggravated the low-temperature condition, causing a further reduction.

Due to the reduced canning load received during the canning season, the digester was able, as in 1951, to handle all sludge. Therefore, the proposed plan of using the digester as a primary digester and the storage tanks as secondary digesters was not put into effect.

The practice of drawing small quantities of sludge often, rather than larger quantities at longer intervals, was continued. Raw sludge is added as digested sludge is slowly drawn at least twice a month to the storage tanks. Ample gas was produced for all needs each day except as previously noted. No storage is available, so gas is used as produced.

Sludge Drying

The first sludge was drawn to the drying beds on April 28, the last on November 12. The first beds were cleaned early in April, and the last late in November. Between these dates 90,660 sq. ft. of beds were cleaned, or 16,240 sq. ft. more than during the wet year of 1951 when drying was slow and large quantities had to be lagooned. No sludge was lagooned in 1952. At year's end two beds totaling 7,980 sq. ft. were clean, ready for early spring use. Several other beds had but a thin layer of almost dry sludge on them and with an open winter might be cleaned before spring.

All sludge stockpiled and on the beds early in the spring was delivered to users and many orders had to be refused after available sludge was gone. Sludge stockpiled during the summer was all delivered late in the fall for use in building new lawns.

Canning Wastes

The canning plant started the year's operation on June 20, when the pea pack was started. This pack was completed on July 21, with some peas packed on 29 days. The corn pack was started on August 9 and completed on September 20, with corn being packed on 40 days. Lima beans were packed on 40 days between August 13 and October 3. The year's operation was completed on October 3 after a fine corn and lima bean crop had been canned and a pea pack which was below average.

Wastes from this plant were handled in the same manner as in 1951. A predetermined amount of canning wastes was allowed to flow to the sanitary sewer, as it was produced, after passing through a vibrating fine screen. The rate of flow allowed to go to the sanitary sewer was varied according to the crop being packed at the time and the ability of the District's plant to handle this extra load. All waste produced in excess of that going to the sanitary sewer was pumped to a waste lagoon at the canning plant after the addition of sodium nitrate.

All wastes in the lagoon from the 1951 pack were drained to the sanitary sewer at a low rate during the early spring, and the lagoon was empty by June 20, when the 1952 pack was started. By October 3, when the pack ended, the lagoon was nearly full and the valve was opened as soon as the pack was completed. Some of the wastes were drained to the sanitary

sewer until October 13, when the valve was closed to give the treatment plant a chance to recover from the heavy load it had been treating all summer. The valve was again open between November 25 and December 11, the level of wastes in the lagoon being lowered considerably. The balance of the lagooned wastes will be treated through the District's plant during high sewage flows in the spring. Under this plan no trouble was experienced at the treatment plant during the canning season.

Table I is a summary of operating data for 1952.

TABLE I.—Summary of 1952 Operation Data, DeKalb (Ill.) Sanitary District

Item	Average	Item	Average
Rainfall, total (in.)	29.64	B.O.D. (p.p.m.):	
Tributary population	14,000	Raw	223
Sewage flow (m.g.d.):		Settled	123
Average	1.69	Filtered	49
Maximum	2.36	Final	45
Minimum	1.15	Reduction (%)	76
Screenings (cu. ft./m.g.)	1.2	Digester gas produced (1,000 cu. ft./day)	11.5
Sludge pumped (1,000 gal./day)	3.8	(cu. ft./cap./day)	0.82
Suspended solids (p.p.m.):		(cu. ft./m.g. sewage)	7,185
Raw	181	Operating cost ($):	
Settled	75	Total	14,751.12
Filtered	70	Per capita	1.054
Final	52	Per m. g. sewage	23.81
Reduction (%)	71		

Annual Report of the Jackson, Mich., Sewage Treatment Plant for the Fiscal Year Ending July 1, 1953 *

By R. A. Greene, *Superintendent*

Reduced sewage flow and grit accumulation, with correspondingly higher suspended solids and B.O.D. concentrations, resulted from the exceptionally low total precipitation that occurred in the last half of the report year. The total quantity of both suspended solids and B.O.D. removed, however, remained about the same as in the previous year.

Although a good effluent was produced almost continuously, industrial wastes did cause considerable trouble at times, particularly wastes from plating industries. On one occasion the activated sludge process was almost upset. This occurred on April 16, 1953, when the raw sewage sample at 11:00 PM contained in excess of 100 p.p.m. of both chromium and cyanide. This happened during a rainstorm when a flow exceeding the designed capacity of the aeration tanks was being treated. As a result, the final effluent contained as much cyanide as the raw sewage. This no doubt caused the fish kill in the Grand River noted a day or so afterward. It took about a week to get the activated sludge process back to normal. There were several other times when these wastes came into the plant in such concentrations as to be troublesome. A new sewer ordinance is being prepared and it is hoped that the ordinance plus more education and understanding will result in a better use of the sewer system.

The diffuser plates in the pre-aeration channel at the primary settling tanks and all the diffuser plates in the aeration tanks were replaced during the year. As was described in the 1950–1952 reports the old plates had become clogged to such an extent it was

* For last previous extract see This Journal, **25**, 4, 500 (Apr., 1953).

difficult to get sufficient air through them for the aeration process. Since the rehabilitation of these tanks, the pressure has held consistently at 6.6 lb. It has not been necessary to add chlorine to the air lines to prevent clogging since this work was completed. About once every two months an additional blower is operated for 2 to 4 hr. It is hoped this will prevent clogging and thereby lengthen the period between plate cleaning. Heretofore it has been necessary to clean plates every 5 years.

Sludge Digestion and Disposal

The six digesters are still being operated as two three-stage units, with raw sludge being pumped to the two units on alternate days. Practically all digestion was completed in the first and second stages, with the third-stage digesters serving principally for concentration of sludge. Supernatant of low solids content was drawn from the second- and third-stage digesters. Digested sludge was drawn to the drying beds from the third-stage digesters. It was necessary to completely dewater both first-stage digesters and both second-stage digesters to remove a 4-year accumulation of scum and sand. The sand causes the most trouble, in that the lower heating coils become imbedded in it, making heating of the tanks difficult. There was a large amount of oil in the scum; when this had come to the top in the lagoon into which the digesters were dewatered, it was burned. Gas production was down somewhat during the year and it appears there were two and possibly three reasons for it. First, the dewatering of the digesters resulted in low gas production for the two months this operation was in progress. Secondly, it is felt that plating wastes caused interference at times. On two or three occasions the pH of the first-stage digesters was below 7.0 and the total alkalinity was down around 1,500 p.p.m. An effort has been made to operate the first-stage digesters so as to keep the alkalinity up to at least 1,800 p.p.m. Thirdly, the wide use of detergents might have had an adverse effect on the gas production.

Sludge bed cleaning has been done by inmates from the State Prison of Southern Michigan. The sludge was hauled to prison farms in plant owned and operated trucks. This provides the state institution with approximately 1,700 tons of fertilizer and soil conditioner at a low cost, as well as providing the city with an economical method of disposing of the dried sludge. Fifty-three sludge beds were cleaned during the year, each bed having an area of 7,500 sq. ft. The equivalent of 33 beds were also cleaned from the shallow lagoons by the prison inmates. One of the two deep lagoons was also cleaned with the use of a crane. Sludge was available to the general public without charge from a stockpile on the plant grounds.

Sewage Service Rates

The sewage treatment plant has again been operated as a utility. The charge to both domestic and industrial users is based on the amount of water used. Customers outside the city limits, both domestic and industrial, pay double rates. The revenue was used for the following purposes: operation and maintenance of the treatment plant, operation and maintenance of the three pumping stations and the many diversion chambers, cleaning and maintenance of sewers, an amount assessed the plant in lieu of taxes, one-half of the cost of billing and collection of water and sewage service bills, one-half the cost of meter reading and maintenance, bond retirement and interest, and plant additions and improvements. The revenue was sufficient to cover all these costs and still have a balance. As stated in the previous annual report, sufficient funds are on hand to pay off all outstanding bonds.

The engineering firm that made an

engineering study of the city's water pumping plant and water distribution system and proposed water rate schedules at the same time proposed a new rate schedule for sewage service. The proposed rate schedule was adopted by the city commission to become effective July 1, 1953. The sewage rates were lowered approximately 20 per cent, this being the percentage of the total revenue required annually for bond retirement and interest.

Table II summarizes operation data for the fiscal year 1952–3.

TABLE II.—Summary of Operation Data for the Jackson (Mich.) Sewage Treatment Plant for the Year Ending July 1, 1953

Item	Average
Connected population (est.)	50,000
Rainfall, total (in.)	26.70
Sewage treated:	
M.g.	3,140.82
M.g.d.	8.60
G.p.c.d.	172
Grit (cu. ft./mg.)	0.83
Sewage analyses:	
Suspended solids:	
Raw (p.p.m.)	198
Settled (p.p.m.)	167
Final (p.p.m.)	14
Per cent reduction	93
B.O.D.:	
Raw (p.p.m.)	130
Settled (p.p.m.)	106
Final (p.p.m.)	7
Per cent reduction	95
Lb. per cap. per day in raw	0.187
Dissolved oxygen (p.p.m.):	
Raw	2.9
Settled	3.0
Final	4.3
Oxygen consumed (p.p.m.):	
Raw	51.4
Settled	42.9
Final	11.9
Organic nitrogen (p.p.m.):	
Raw	8.0
Settled	8.1
Final	3.2
Ammonia nitrogen (p.p.m.):	
Raw	10.4
Settled	11.5
Final	11.5
Nitrite-nitrate nitrogen (p.p.m.):	
Final	0.0
Aerators:	
Mixed liquor susp. sol. (p.p.m.)	2,100
Sludge index	39
Air used (cu. ft. per gal.)	0.7
Primary sludge:	
Per cent solids	4.6
Per cent volatile	61
Lb. dry solids removed per m.g. sewage	1,518.21
Gal. per m.g. sewage	4,068
Return sludge (per cent)	20
Gas production:	
Total (1,000 cu. ft.)	16,762
Gas per lb. vol. sol. digested (cu. ft.)	12.3
Cu. ft. per capita per day	0.92
Cost data ($):	
Cost of operation	88,234.49
Revenue bonds (retirement and interest)	41,557.25
Collection (billings, etc.)	19,301.09
New equipment	1,066.97
Lift stations and sewer maintenance	33,805.58
Insurance	1,011.40
Taxes and meter maint.	23,977.20
Total	208,947.98
Cost per m.g. (fixed charges included)	66.52
Cost per m.g. (less fixed charges)	34.24

SOME NOTES ON CONTEMPORARY GERMAN PLANTS

By Gordon E. Mau

Chief, Water Pollution Control Section, Kansas State Board of Health, Lawrence, Kansas

Editor's note:—The plants described and pictured in this article were visited by the author in the course of a trip to Europe during the Fall of 1952. These few notes have been selected by him as depicting new or unusual items of interest from a large selection of pictures shown at the Operator's Forum during the Miami meeting of the Federation, held October 13–16, 1953.

Kettering Plant

The Kettering sewage treatment plant (Figure 1), located in the Ruhr River basin in Germany, was built in 1952. The picture was taken from the top of a pumphouse located between two trickling filters. Sewage is pumped from the primary settling basin, which is the lowest basin in the center of Figure 1, to the trickling filters, from where it flows by gravity to the final settling basin in the foreground. In the left foreground is the heated, covered digester and the maintenance shop. The building in the right center houses the ferrous sulfate feeders and the pre-aeration compressors. The duplex house in the center background provides living quarters for the two main plant operators. Digester gas provides heat for the house, as well as for plant use.

Kemper Plant

Industrial waste from a rayon cloth dyeing plant has created a color problem at the Kemper sewage treatment plant in the Niers River basin. The plant receives approximately 6,000 cu. m. of sewage flow per day (1.58 m.g.d.) from a population of 23,000, plus the industrial waste. Frothing of the

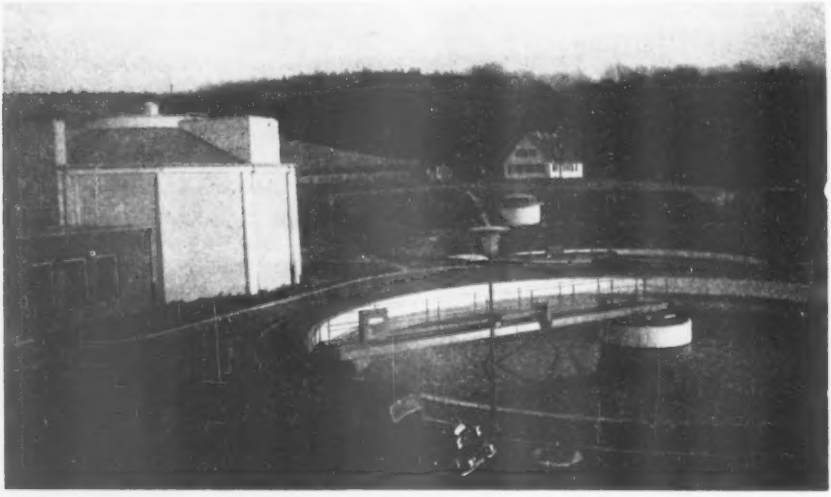

FIGURE 1.—Kettering sewage treatment plant in Ruhr River basin, Germany, was constructed in 1952.

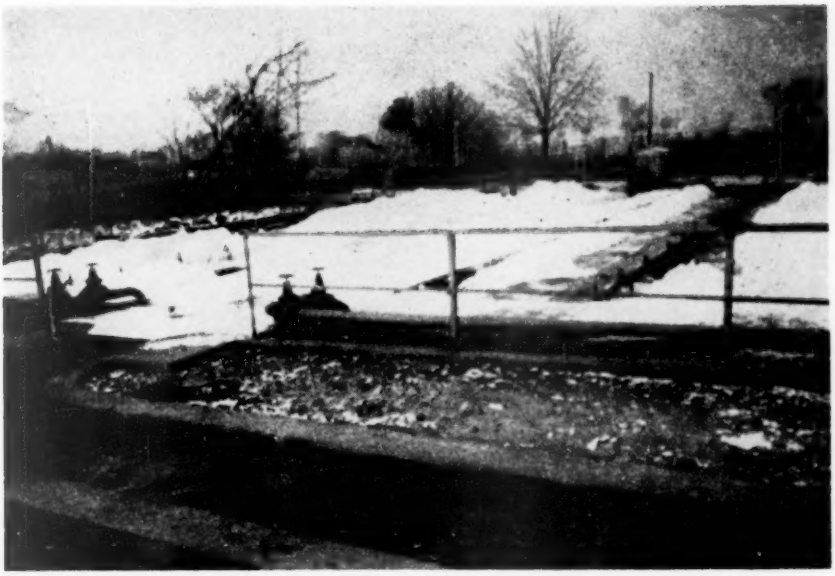

FIGURE 2.—Frothing of aerators at Kemper sewage treatment plant creates nuisance and safety hazard.

aerators (Figure 2) has created a nuisance problem, as well as a safety hazard on plant walks. Special attention is called to the flow division baffles at the channel turn in the lower left-hand corner of Figure 2.

Gruppen Plant

The new method of adding settled sewage to the aerator of the Gruppen sewage treatment plant, located in the Niers River basin, is shown in Figure 3. After visiting the United States and observing increment feeding of settled sewage to activated sludge aerators, Mr. Schmitz-Lenders, Chief Engineer, Niers River Authority, decided to try the method in the Gruppen plant.

After studying the problem and the construction of the aerators he concluded that the structure in the middle of the aerator, originally intended to effect spiral flow in each half of the aerator, could be adapted for purposes of carrying settled sewage. Then, instead of feeding the sewage at isolated points, V-notch weirs similar to those used in settling basins were added on both sides along the entire length of the channel. Sewage flows through the notches onto a perforated tray and thence into the aerator.

The original purpose in adapting this type of feeding to the existing aerators was to obtain a better activated sludge and to enable the aerators to stand a shock loading better than where all of the settled sewage and activated sludge are added at the inlet end of an aerator. After the new method of feeding was placed in operation, however, it became apparent that the following additional improvements were being realized:

1. Froth is controlled, as shown in Figure 3, which shows that the aerator receiving settled sewage along its entire length is relatively free of froth, whereas the adjoining aerators, receiving settled sewage and activated sludge only at the inlet end, have considerable froth.

FIGURE 3.—Addition of settled sewage to one aerator of the Gruppen plant through V-notch weirs extending the entire length of the tanks gives marked improvement in operation.

2. The sewage is mixed quickly and uniformly with the aerator contents.

3. The sewage is added on the opposite side of the aerator from the air, thereby aiding in maintaining spiral flow in the aerator, which in turn keeps some air bubbles in the tank for a longer period.

In December, 1952, the aerator capacity at this plant was being approximately doubled, with the new method of feeding being provided in all of the new aerators. It also was intended to reconstruct all of the old aerators for this method of feeding after the new units were in operation.

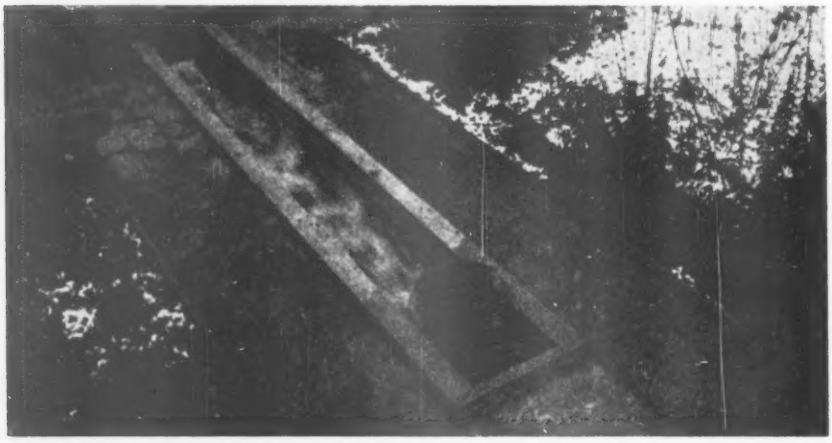

FIGURE 4.—Simple paddle-wheel device minimizes froth formation in trickling filter effluent channel at the Hagen sewage treatment plant.

The Gruppen plant receives approximately 60,000 cu. m. of sewage per day (15.85 m.g.d.) with a population equivalent of 800,000. Included in this is a population equivalent of approximately 200,000 from textile industries (dyers and bleachers), with some also being contributed from brewing, tanning, and straw and reclaimed paper industries. The treatment plant was being expanded in anticipation of connecting an additional 60,000 to the sewer system and inclusion of additional industrial wastes that will increase the waste strength at the treatment plant by 60 per cent.

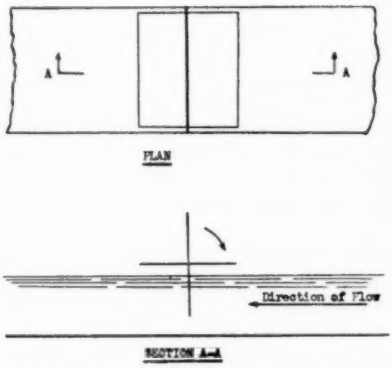

FIGURE 5.—Operational sketch of froth control device in open trickling filter effluent channel.

Hagen Plant

A simple device (Figures 4 and 5) effectively minimizes froth formation in the open trickling filter effluent channels at the Hagen sewage treatment plant, located in the Ruhr River basin. The paddles, turned by the flow, simply submerge the froth in the liquid. Before the paddle wheel was placed in the channel froth formed in the filter effluent to such an extent that it covered the walks and blew around the plant yard, causing both a safety hazard and an unsightly appearance. The device seems to offer a method by which froth formation in channels can be controlled without resorting to sprays or other devices requiring mechanical equipment and maintenance.

TIPS AND QUIPS

Unexplained Explosion

The source of the digester gas and the spark leading to an explosion in the service building of the Bethalto, Ill., sewage treatment plant reportedly still had not been determined according to a recent issue of *The Digester.** The explosion occurred at 10:20 PM on June 12, 1953.

Workmen were in the building as late as 5:30 PM, but noticed no gas in the building at that time. A number of automatic electrical devices might be blamed for igniting the gas, but none of these was near the main force of the explosion.

Fortunately, none of the operating personnel was in the building and damage to the plant was slight. Whatever the cause, and regardless of the slight damage, however, the incident should serve as a reminder to all that gas safety precautions are necessary every minute.

* Vol. 15, No. 3 (Aug., 1953).

Electrical Causes of Fire

In an excellent 24-page booklet entitled "Fire Control—It's Equipment, Personnel and Procedure," a section devoted to electrical causes of fires should prove of especial interest to plant superintendents and operators. This, however, is only one of the many thought-provoking discussions of fire hazards and fire-fighting methods discussed in the booklet, which is available from your plant insurance underwriter

or through the Association of Casualty and Surety Companies, 60 John St., New York, N. Y. As regards electrical causes of fires the pamphlet says:

"Fires caused by electrical conditions are generally due to arcs, sparks, and overheating, and are for the most part the result of faulty maintenance or operation of equipment, or overloaded circuits.

"Motors are subject to arcing and sparking if dirty or out of alignment and should be protected from dampness, corrosion, and from accumulations of dirt and dust.

"Motors should be checked regularly. Those in hazardous locations should be of the explosion-proof type and should be cleaned frequently so that their cooling will not be retarded.

"Under no circumstances should fuses be used of greater amperage that the circuit is designed to carry.

"Switchboards should be inspected for loose connections, and the adjacent area should be kept free of combustibles.

"Transformer gauges should be checked to see that oil is maintained at the proper level. Wiring should be protected from corrosion due to acids or corrosive vapors, or electrolysis, heat, and moisture.

"All electrical equipment and installations should conform to the accepted national standard electrical code."

Quarter Century Operators' Club Notes

Meeting for the twelfth time at the Federation's Miami meeting (October 13-16, 1953), the Quarter Century Operators' Club noted the passing of two members and the qualifications for membership of two others. The two deceased members were George C. Behnke and Stuart E. Coburn.

The two newly qualified members were Floyd G. Browne, currently Consulting Engineer, Marion, Ohio; and G. L. Fugate, currently Chief Design Engineer, Department of Utilities; Houston, Tex. The roster includes 42 active members.

To be eligible for membership in the Quarter Century Operator's Club, the candidate must have been in full-time resident charge of the operation of a sewage treatment plant 25 years prior to the date of their admission to the Club. Eligible persons are urged to contact the Registrar of the Club, whose address is: Frank W. Jones, c/o Havens & Emerson, 1140 Leader Building, Cleveland 14, Ohio.

Safety Step Ladder

An "automatic action" safety step ladder that can be easily rolled to position then automatically locks in position, is now available. The rubber-tipped legs "lock" to the floor automatically when a person steps on the positioned ladder, the casters disengaging by the same action. Information on the aluminum-finished steel-tubing unit is available from Precision Equipment Co., 3714 N. Milwaukee Ave., Chicago 41, Ill.

Troublesome Wood Preservatives

Increased use of pentachlorophenol as a wood preservative has made treatment of the wastes from the Koppers creosoting plant at Carbondale, Ill., increasingly difficult, according to *The Digester* (**15**, 3, 8; Aug., 1953). Experience has been that when creosote and "penta" are mixed, an extremely difficult emulsion is formed.

The creosote wastes had been treated by sedimentation, separation, coke absorption, and lagooning. The emulsion formed by the mixture of the two preservatives coated the coke surface of the absorption unit, making its use impractical.

Treatment of the "penta" waste now consists of keeping it completely separated from the creosote waste and reclaiming the "penta." Creosote waste is treated as it was formerly.

Federation Affairs

TWENTY-SIXTH ANNUAL MEETING REPORT

The 26th Annual Meeting of the Federation, held at the Bayfront Park Municipal Auditorium in Miami, Florida, on October 13–16, 1953, attracted a total registration of 805, the fifth highest in the history of these meetings. The 199 ladies included in this total constituted the third highest ladies' registration on record. Geographically, members or guests were registered from 35 states, the District of Columbia, Canada, Puerto Rico, England, Sweden, Dominican Republic, and Cuba.

For the outstanding success of the meeting in all its phases, great credit is due the host Florida Sewage and Industrial Wastes Association, and the Local Arrangements Committee, headed by Caesar F. Wertz. The enjoyable atmosphere of the meeting was a result of the great attention given to planning details by the various local committees comprising the last group.

The 26th Annual Meeting was convened at 10:30 AM on Tuesday, October 13, 1953, by President E. Sherman Chase, who welcomed the attendants and commented briefly on the activities of the Federation. The Executive Secretary-Editor's report, by W. H. Wisely, concluded the business portion of the opening session.

Technical Program

The technical program, developed by the Program Committee under the chairmanship of F. W. Gilcreas, presented topics of broad general interest as well as many papers on specific pollution and waste treatment problems. Both the Industrial Waste Forum and the Operator's Forum were well attended and received. The lively discussion of the several topics chosen for each was indicative of the great interest aroused.

The technical program presented at Miami was as announced in the "26th Annual Meeting Preview" (THIS JOURNAL, 25, 9, 1120; Sept., 1953). Technical program papers are to be published in 1954 issues of the Journal, beginning with this issue.

Entertainment Events

A "Family Night Entertainment" on Tuesday evening, October 13, featured several unusual variety acts by professional talent.

The Federation Luncheon, held in the Starlight and Panorama Rooms of the Biscayne Terrace Hotel on Wednesday noon, was attended by a capacity crowd of 250. After recognition of the activity of the Quarter Century Operators Club, Dr. Wilson T. Sowder, Florida State Health Officer, spoke on "Sanitation Problems in Florida."

The Annual Federation Awards Dinner, held in the Auditorium on Thursday evening, October 15, was attended by 560 members and guests. At the dinner, President Chase presented the annual Federation awards and introduced the new officers. Dancing followed at the Biscayne Terrace Hotel to complete an enjoyable evening.

Ladies' Entertainment

The excellent entertainment features planned for the ladies by the local Ladies' Entertainment Committee, under the chairmanship of Nevin Hoy, were the subject of much favorable comment by the large group of ladies attending the meeting. Even the unusual rainfall occurring during the period of the meeting seemed to be scheduled to allow maximum enjoyment of the ladies' events.

Post-Convention Trip

Following the scheduled events of the meeting, 21 persons took advantage of the opportunity afforded to participate in an excursion trip to Havana and the Cuban countryside, returning to Miami on the morning of October 19.

Manufacturers' Exhibit

As a co-feature of the Miami meeting, the Water and Sewage Work Manufacturers' Association showed new equipment and process developments in an exceptionally interesting and informative exhibit. All space allotted for displays was fully utilized by the various manufacturers to make the exhibit one of the most outstanding thus far.

Florida Association Luncheon and Annual Meeting

The Florida Sewage and Industrial Wastes Association, host of the Federation meeting, held its 1953 Annual Meeting following an Association luncheon on Tuesday, October 13.

At the short business meeting, President Chase conveyed the Federation's official expression of gratitude and appreciation for the excellent manner in which the Florida Association carried out its responsibilities as host to the 26th Annual Meeting.

Officers elected by the Florida Association for the year 1953–4 were as follows:

President: W. C. Tims, Tampa.
Vice-President: P. Flanagan, Tampa.
FSIWA Director: J. E. Kiker, Jr., Gainesville.
Secretary-Treasurer: D. P. Schiesswohl, Jacksonville.

The L. H. Scott Award for the best-operated sewage treatment plant in Florida was presented to Joseph J. Raye, Superintendent at Clearwater. John W. Wakefield was nominated to receive the Federation's Arthur Sidney Bedell in 1954 for his services to the Florida Association, of which he was the retiring President.

BOARD OF CONTROL MEETS AT MIAMI

Most noteworthy of the actions taken at the 26th Annual Meeting of the Federation Board of Control at Miami was the provisions made for emphasizing research functions. The headquarters staff will be strengthened by the addition of an administrative assistant, thus enabling the Executive Secretary to devote more attention to the stimulation of needed research in the Federation's area of interest.

The proposed research program will encompass the following basic elements, subject to modification as experience may indicate:

1. Maintenance of a directory of research agencies, public and private, with information on staff, facilities, and specialized interests.

2. Periodic surveys of research projects under study, results to be made available to all research agencies.

3. Continuing contact with all elements of the field to determine specific problems for which the immediate need for study is greatest.

4. Encouragement of research on the current problems involving need for fundamental study.

5. Establishment of the Federation as a clearing house for exchange and dissemination of research information.

Forty officers and directors answered roll call for the meeting of the 1953 Board on October 12, and 38 attended the October 16 organization meeting of the 1954 Board.

New Officers

The following officers were elected on October 12 for the terms indicated:

President: Louis J. Fontenelli, Garwood, N. J., to October, 1954.
Vice-President: David B. Lee, Jacksonville, Fla., to October, 1954.
Treasurer: W. W. DeBerard, Chicago, Ill., to October, 1954.
Director-at-large: Vernon G. Mackenzie, Cincinnati, Ohio, to October, 1956.

Constitution Amendments

Amendments to the Constitution and By-laws as adopted at Miami provide for establishment of a permanent Committee on Standard Methods of Sewage and Industrial Wastes Analysis, with the chairman to be an ex-officio member of the Board of

Control. This important committee has not previously had "constitutional" status.

The Board also initiated amendments to the By-laws that would eliminate the specific statement of the amount of dues to be paid by Sustaining and Associate Members. The proposed amendment, leaving these dues for determination at the pleasure of the Board, will be acted upon by letter ballot.

1953 Awards

The following honors and awards, as conferred by the Board, were presented or announced by President Chase at the Annual Awards Dinner on October 15:

Elected as Honorary Members were Karl Imhoff of Essen, Germany, and Harold Warner Streeter of Cincinnati, both internationally-known pioneers in the field.

The Harrison Prescott Eddy Medal was earned by Donald M. Pierce of Lansing, Michigan, for his research contribution "Two-Stage Chlorination—An Effective and Practical Method of Sewage Disinfection."

The George Bradley Gascoigne Medal was conferred upon W. N. Wells and Clarence H. Scherer for their plant operation contribution entitled "Froth Formation and Synthetic Detergents."

The Industrial Wastes Medal was awarded to Richard H. Coe of the Shell Oil Company at Wilmington, Calif., for his contribution "Bench-Scale Biological Oxidation of Refinery Wastes with Activated Sludge."

For his many years of faithful service to the Federation, notably as chairman of the Standard Methods Committee, William D. Hatfield of Decatur, Ill., received the 1953 Charles Alvin Emerson Medal.

Nominations for the 1953 Arthur Sidney Bedell awards, for service to Member Associations of the Federation, were confirmed by the Board as follows: Robert James Auld (Puerto Rico); Charles G. Caldwell (Rocky Mountain); Nathan Meredith deJarnette (Georgia); Anthony J. Fischer (New York); Ralph Edward Fuhrman (Maryland-Delaware); Quintin B. Graves (Oklahoma); John B. Kleven (Dakota); Douglas Lachlan McLean (Canada); Walter E. Merrill (New England); Fred F. Palmer (Montana); Eugene C. Meredith (Virginia); Henry Withers Speiden (West Virginia); and Arthur Thomas Wintersgill (California).

The Executive Committee was directed to study changes in the present plan of granting all Member Associations, regardless of size, one Bedell award nomination in each three years. This rule is held by some of the larger associations to limit the recognition that should be given to worthy candidates.

Operation Manual Authorized

A good year of progress was reported by the Sewage and Industrial Wastes Practice Committee in its Manual of Practice Program. The manuals on paints and protective coatings and on reporting units for plant design and operation are soon to be ready for distribution for critical review. A new committee has made an excellent beginning with the sewer maintenance manual, and should have a preliminary draft assembled in 1954.

The Board gave hearty approval to the production of a manual under the title "Elements of Sewage Treatment Plant Operation," for which there is a wide need. Appointment of a task committee is underway.

Board sanction was also given to the joint production with the ASCE Sanitary Engineering Division of manuals on sewer infiltration, sewer design, and sewage treatment plant design. These manuals will be published by ASCE, but the task committees will include Federation representatives.

Phelps Memorial Resolution

With a commentary on the inadequacy of any written instrument to do full justice to the motives and accomplishments of the late Earl B. Phelps, the Board adopted the following resolution as submitted by the Florida Sewage and Industrial Wastes Association:

"With the passing of Professor Earl B. Phelps at Gainesville, Florida, on May 29, 1953, the profession of Sanitary Engineering and allied fields has lost one of the great pioneers in sanitary research. Professor Phelps devoted his full life and gave unending service to his fellowmen throughout all walks of life. He brought to his work an originality of mind, a ca-

pacity for mathematical formulation, a breadth of understanding of the fundamental laws of physics, chemistry and biology that permitted him to make some of the most significant contributions that have ever been made in his chosen field of study.

"Professor Phelps' passing occurred during the 21st Annual Short Course for Water and Sewage Plant Operators at the University of Florida. His co-workers and short course students suggested the establishment of the Earl B. Phelps Memorial Fund in commemoration of the humane service the beloved teacher had rendered to his teaching, research and consulting work. The funds will be administered by the University's College of Engineering to support scholarships or research in the field of Public Health Engineering.

"The Federation of Sewage and Industrial Wastes Associations expresses its sincere sorrow in this great loss, and its sympathy to the family. The Federation looks with approval upon the memorial fund, and wishes it a successful and useful tenure."

Membership

The Secretary reported that the aggregate Active and Corporate membership of the 38 associations comprising the Federation was 5,762 on September 30, 1953, a gain of 5.7 per cent for the year.

The California association, with a gain of 58 members, barely won out in the numerical increase contest over the Pacific Northwest association. Puerto Rico easily took the percentage increase prize with a mark of 387 per cent. The winning associations were each awarded $100 prizes.

Competition for both prizes was unusually spirited. Contenders other than those named above were: Nebraska, Ohio, Central States, South Carolina, Arizona, and Oklahoma. The California association was runner-up for the numerical increase prize in 1951 and 1952; it has gained 139 members in the past three years.

Financial

The operating budget adopted for fiscal 1954 is balanced at $100,300. Provision is made for the staff expansion necessary to the increase in research activities, and for an employees' retirement pension plan.

Audited net worth of the Federation was $67,529.78 at the end of 1952. A modest increase is indicated for the year 1953.

Los Angeles in 1956

Cincinnati in 1954 and Atlantic City in 1955 had previously been designated as locations for the annual meeting. Los Angeles has now been officially designated as the 1956 meeting place, with the new Hotel Statler as headquarters.

New meeting place invitations were received from the Central States and Pacific Northwest associations and referred to the committee.

In a further effort to emphasize industrial wastes interests, the Board authorized extension of the technical program at Cincinnati in 1954 to four full days. The extra session will be devoted to industrial wastes papers.

LOUIS J. FONTENELLI NEW PRESIDENT

Louis J. Fontenelli, of Garwood, N. J., became the fourteenth President of the Federation at the organization meeting of the 1954 Board of Control, held at Miami, Florida, on October 16, 1953.

Following his early education in the public schools at Newark and Westfield, N. J., Mr. Fontenelli studied electrical engineering at the Newark Evening Technical School, graduating in 1932, and has since taken several special courses at Rutgers University in sewage treatment and related fields.

From 1920 to 1930 Mr. Fontenelli was engaged in maintenance and power plant operation at the Garwood, N. J., plant of the Aluminum Company of America. He then became Chief Engineer in Charge of Operation, New Jersey Division, Knickerbocker Ice Company, remaining in that position until 1937.

Since 1937, he has been Superintendent of Sewage Treatment for the Rahway Valley (N. J.) Sewerage Authority, a body engaged in the collection and treatment of sewage and industrial wastes from nine New Jersey municipalities.

Mr. Fontenelli has served the New Jersey Sewage and Industrial Wastes Association as President and Vice-President, as well as in many important committee posts. For the past four years he has been a member of the New Jersey State Examining Board for the Licensing of Water and Sewage Treatment Plant and Water Distribution Superintendents. He has also served his community as a councilman and two terms as mayor, and was Director of Civil Defense during World War II. He is currently again serving in the latter post.

In addition to being Vice-President of the Federation in 1953, he has been a member of the Federation Board of Control (1949–51) and has served on the Legislative Analysis Committee (1948), the Executive Committee (1950–51 and 1953), and the Meeting Place Committee (1953). He is at present a member of the last two and also of the Finance and Honorary Member Committees.

DAVID B. LEE ELECTED VICE-PRESIDENT

David B. Lee, Director of the Bureau of Sanitary Engineering, Florida State Board of Health, was elected to the Vice-Presidency of the Federation at the Election Committee meeting on October 12, 1953. The wide experience gained in his many responsible positions in technical organizations, together with his intimate knowledge of the diverse fields covered under the broad heading of sanitation, gives Mr. Lee a particularly good insight into the objectives and aims of the Federation.

Prior to appointment to his present position in 1941, Mr. Lee had served the Florida State Board of Health as field engineer, district engineer, and malaria control engineer. He served in the Sanitary Corps, U. S. Army from 1942 to 1945, commanding the 4th Malaria Control Unit in New Guinea (1943–4). Since 1948 he has been a special consultant to the USPHS on sanitary engineering problems, and was a member of the United States delegation to the Second World Health Assembly in Rome (1949). He is a member of several general engineering societies, as well as the Florida Sewage and Industrial Wastes Association (President 1941–2), American Public Health Association, National Research Council Committee on Sanitary Engineering and Environment, American Water Works Association (Director 1948–51), and the Conference of State Sanitary Engineers (Chairman 1948–9). He is also the recipient of several engineering society awards, including the Federation's Kenneth Allen Award and the Centennial Award of the University of Florida.

In addition to serving as the Florida Director on the Federation Board of Control (1946–9), Mr. Lee also served as a Director-at-Large (1952–3). He has served as a member of the Legislative Analysis, Emergency Planning, and Executive Committees of the Federation. At present he is a member of the Executive Committee and the Meeting Place Committee.

Reviews and Abstracts*

Treatment of Coal Distillery Wastes by the WEV-Process. By Georg Schulz. *Wasserwirtschaft-Wassertechnik*, **2**, 410 (1952).

The principles of the process are as follows:

1. The phenol wastes are adjusted to pH 6.8 by aeration with CO_2. Excess CO_2 forms NH_4HCO_3.
2. The waste passes through a gravel filter to remove oily and mechanical pollution.
3. The liquor then passes through an ion exchanger bed of Wofatit P.
4. After exhaustion the drained bed is washed with methanol.
5. Distillation removes and returns the methanol to the top of the filter.
6. Upflow of rinse water displaces the methanol after extraction.

Each step is discussed in detail. Pilot plant operations using several filters in parallel are described and operating results are given. Raw still wastes, as well as the effluent from the Koppers process, have been treated; for example, a still waste containing 7,600 p.p.m. phenol, 113,500 p.p.m. $KMnO_4$ O.C., and 92,000 p.p.m. 5-day B.O.D. was treated on two parallel filters at 360 l. per hr. for 3 hr. at a space loading of 3.08 cu. m. per cu. m. of Wofatit P, a phenol loading 23.5 kg. per cu. m. of Wofatit P, and a total extract loading of 48.0 kg. per cu. m. of Wofatit P, yielding an effluent containing 5.5 p.p.m. phenol, 3,720 p.p.m. $KMnO_4$ O.C., and 4,450 p.p.m. 5-day B.O.D. Methanol losses were 7.9 l. per cu. m. of raw waste. Extract yield was 15.6 kg. per cu. m. of raw waste. Of the extract, 45.5 per cent comprised steam-volatile phenols. Modifications for large-scale operation, as well as a cost analysis, are given. Economically the process is feasible. Peter K. Mueller

Fifteen Years of the Uthleben Sewage Cooperative. By Karl Holler. *Wasserwirtschaft-Wassertechnik*, **2**, 397 (1952).

Progress and effect of 15 years of sewage farming and technical installations are described. Of about 613 hectares (1,515 acres) 440 hectares received spray irrigation and 173 hectares received trench irrigation. The present maximum sewage flow is about 4,800 cu. m. per day (1.27 m.g.d.) The raw sewage flows through a grit removal unit and thence into a 5,000-cu. m. equalizing lagoon functioning at the same time as a settling basin. This is drained once a year for sludge removal. About 50 per cent of the wet sludge is used directly with cattle manure on the fields. The other 50 per cent is dried on beds and composted with garbage. The sewage is pumped to the land through movable pipes. The importance of proper timing of irrigation is emphasized and illustrated for grains (oats, wheat), beets, rape seed, and pastures. Comparisons of crop yields with non-irrigated surrounding areas are given. Peter K. Mueller

Disposal of Industrial Waste Waters in Great Britain. By B. A. Southgate. *Chem. and Eng.*, p. 1231 (1951).

The disposal of waste in Great Britain is governed by the Rivers Pollution Prevention Act, 1923, which sets a standard of 30 p.p.m. suspended matter and a B.O.D. of not more than 20 p.p.m. Under the Public Health Act, 1937, the power to exclude effluents "which would damage the sewers or interfere with the treatment process" is left in the hands of the local authorities. Pretreatment of industrial waste waters revolves about the removing

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

of toxic substances and waste cutting oils from the metal industries. Re-use of waste waters in the manufacturing process is widespread where the volume is so polluting in character that safe discharge into a moderate-size river would be costly. The disposal of liquor from the manufacture of coal gas forms a problem in Great Britain that still presents many difficulties.

R. E. ANDERSON

Treatment of Waste Waters from a Paper Mill by Biological Filtration. BY G. E. EDEN, E. E. JONES, AND A. B. WHEATLAND. *The Paper Maker and British Paper Trade Jour.*, Midsummer (1952).

The removal of the soluble organic polluting matter in waste waters from a paper mill is accomplished by biological treatment in a pilot plant by the use of trickling filters. The use of trickling filters will give an effluent of good quality only when "the pH value of the mixed waste water is adjusted, the residual chlorine (of the paper mill effluent) is removed, and the deficiencies in the content of nitrogen and phosphorus are made good by the addition of inorganic compounds of these elements." The cost of operation of the pilot plant is considerable, two-thirds of which represents ferric chloride. Extensive tables and diagrams accompany the article.

R. E. ANDERSON

The Influence of Trade Wastes from a Gelatine Factory on the Krugersdorp Purification Works. BY J. J. PIENAAR. *Pub. Health* (S. Africa), **16**, 8, 179 (1952).

The effluent of a gelatine factory constitutes 20 per cent of the sewage treated daily at the Krugersdorp Works and is comprised of 3 tons of inorganic solids (mainly lime) and 1½ tons of protein in solution that pass through the plant daily. Two problems are created: first, a rapid corrosion of a concrete sewer with $CaCO_3$ (boiler scale); second, a deterioration of the digested sludge and an increase in drying time from three days to four weeks. To solve these problems, pretreatment of the factory effluent was chosen over two other alternatives. The chosen alternative was to combat the two objectionable factors, the high pH and the high protein content, by the construction of a pilot plant to treat the factory effluent with the combustion products of sludge gas; and, thereby, precipitating the calcium ions as insoluble calcium carbonate, which would serve in turn to flocculate the suspended proteins, thus making the wastes more amenable to treatment.

R. E. ANDERSON

Round-The-Year Cleaning Prevents Clogged Sewers In Dayton, Ohio. BY W. E. MACY. *American City*, **68**, 83 (Aug., 1953).

Generally speaking, Dayton's storm sewers are cleaned by the bucket method, while its sanitary sewers are cleaned with flexible rods. The latter are thus maintained about every two years, and the former less frequently. However, a regular schedule for both systems is in continuous operation. "This preventive program of cleaning . . . is paying dividends in fewer stoppages and happier citizens."

RAYMOND E. ANDERSON

BOOKS, REPORTS, AND PAMPHLETS

Tentative Standard Specifications for Asbestos-Cement Water Pipe. AWWA c400–53T. Amer. Water Works Assn. Price, $0.20 (1953).

Wappinger Creek Drainage Basin. Lower Hudson River Series Report No. 3, N. Y. State Water Poll. Control Board, Albany, N. Y. 33 pp. (1953).

Tokyo's Water Works and Sewerage. Water Works Bur., Tokyo Metropolitan Govt., Tokyo, Japan. In English, 50 pp. (1953).

A well-illustrated but concise booklet describing the several water sources and treatment facilities of this area comprising about 6,500,000 population, the general condition of the metropolitan sewer system and sewage treatment works, and the plan for extension of the sewer system and treatment facilities.

Washing Our Water: Your Job and Mine. BY HELEN B. WOODWARD. Pamphlet No. 193, Public Affairs Pamphlets, 22

E. 38 St., New York 16, N. Y. Price, $0.25 (1953).

Air Pollution Abatement Manual, Bibliography Appendix 2. Manufacturing Chemists Assn., Washington, D. C. 20 pp. Price, $0.35 (1953).

A compilation of references of the last half of 1952 to bring the manual's bibliography (see THIS JOURNAL, **25**, 2, 238; Feb., 1953) up to date.

Corrosion Resistance of Copper and Copper Alloys. Publ. B-36R, American Brass Co., Waterbury 20, Conn. (1953).

A Survey of Agricultural, Forestry and Fishery Products in the United Kingdom and Their Utilization. (British) Development Commission. H. M. Stat. Off., London. Price, 7*s* 6*d* (net) (1953).

This report, based on a survey dated June, 1951, gives references to the conservation of raw materials by by-product recovery and utilization.

American Standard Specifications for Cast-Iron Pit-Cast Pipe (A21.2—1953; AWWA C102-53). Amer. Water Works Assn. Price, $0.45 (1953).

American Standard Specifications for Cement Mortar Lining for Cast-Iron Pipe and Fittings (A21.4–1953; AWWA C104-53). Amer. Water Works Assn. Price, $0.35 (1953).

American Standard Specifications for Cast-Iron Pipe Centrifugally Cast in Metal Molds (A21.6–1953; AWWA C106-53). Amer. Water Works Assn. Price, $0.40 (1953).

Radioactive Waste Removal in a Trickling Filter Sewage Plant. BY A. L. BILADEAU. U. S. Atomic Energy Comm., Tech. Inf. Branch, P. O. Box 1221, Idaho Falls, Idaho (1953).

Planning and Constructing Sewage Disposal Facilities. BY CARL M. FRASURE, HAROLD J. SHAMBERGER, AND EUGENE R. ELKINS. W. Va. State Water Comm., Charleston, W. Va. (1953).

Published cooperatively by the West Virginia State Water Commission and the West Virginia Department of Health, this is a guide for municipal officials for planning, constructing and financing sewers and sewage treatment facilities in West Virginia.

Reclamation of Municipal Refuse by Composting. Tech. Bull. No. 9, Series 37, San. Eng. Res. Lab., Univ. of California. Price, $1.00 (1953).

This is a very fine report on a composting study covering practically every phase of the subject. Important features are the outlines of the historical development and the present status of composting throughout the world, and an excellent bibliography on the subject.

Sewerage and Drainage of the Greater Vancouver Area, British Columbia. BY CHARLES G. HYDE, JOHN OLIVER, AND A. M. RAWN. Vancouver and Districts Joint Sewerage and Drainage Board, Vancouver, B. C. 278 pp. Price, $10.00 (1953).

Great South Bay—Easterly Section Drainage Basin. Suffolk County Survey Series Report No. 3, N. Y. State Water Poll. Control Board, Albany, N. Y. 18 pp. (1953).

Accident Facts. National Safety Council, 425 N. Michigan Ave., Chicago 11, Ill. (1953).

The 1953 edition of an annual compendium of statistics for all types of employment, motor vehicle, home, farm, school, transport, and nontransport accidents. Extremely revealing as to deaths and injuries involved.

Lake Erie (East End)—Niagara Drainage Basins. Lake Erie—Niagara River Drainage Basin Series Report No. 3, N. Y. State Water Poll. Control Board, Albany, N. Y. 43 pp., 14 tables, 11 graphs, 10 figures, and 13 maps (1953).

Power and Fluids. Worthington Corp., Harrison, N. J.

A new company magazine, to be issued quarterly, describing new product applications, processes, and methods. Distribution by request to the publisher.

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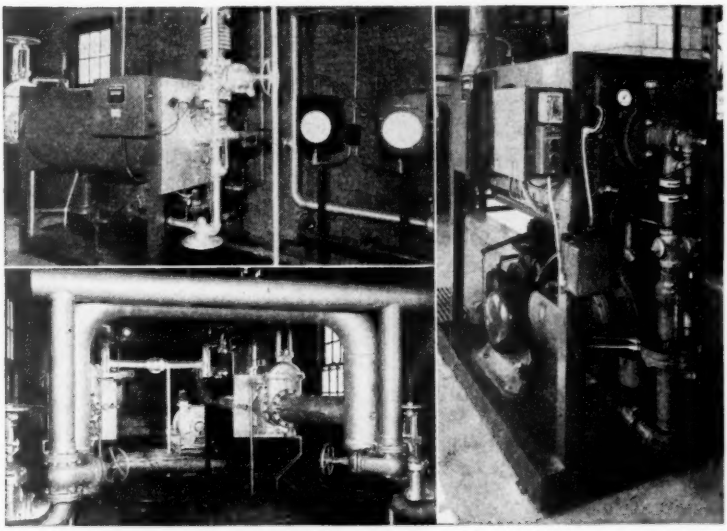

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Proceedings of Member Associations

ALABAMA WATER AND SEWAGE ASSOCIATION

The 1953 Annual Meeting of the Alabama Water and Sewage Association was held in conjunction with the Annual Short Course School at the University of Alabama, Tuscaloosa, Ala., on June 8–12, 1953. A total of 106 persons were registered.

In addition to the usual short school subjects, papers of interest to sewage works personnel included the following:

"Jefferson County Sewerage Works Program," by R. C. Barton, Sanitary Engineer, Jefferson County.

"Financing Water and Sewerage Works," by James R. Hendrix, Birmingham.

"Water and Sewage Facilities in Foreign Countries," by John M. Henderson, Deputy Chief, Technical Development Section, USPHS.

Inspection trips were made to the Village Creek sewage treatment plant and the Dickey Clay Pipe Company plant, both in Birmingham.

Officers elected to serve during 1953–4 were as follows:

President: C. W. Veazey, Alexander City.
Vice-President: C. Lamon, Prichard.
Secretary: A. O. Taylor, Auburn.
Treasurer: L. Hubbs, University.

ALEX O. TAYLOR,
Secretary

GEORGIA WATER AND SEWAGE ASSOCIATION

The 1953 Annual Meeting of the Georgia Water and Sewage Association was held at the Georgia Institute of Technology, Atlanta, Ga., on September 23–25, 1953, in conjunction with the Annual Georgia Water and Sewage School. Of the 362 registered for the event, 67 were from the sewage field.

Papers of particular interest to wastes treatment and pollution control personnel were as follows:

"The Water and Sewage Plant Operator's Place in the Sun," by James E. Jackson, Chairman, Water Committee, Atlanta.

"Safe Practices for Water and Sewage Plant Operators," by W. N. Cox, Jr., Professor of Safety Engineering, Georgia Institute of Technology, and W. E. Burnette, Chairman, Safety Committee, Water Dept., Atlanta.

"Suggestions for Self Study," by Linn H. Enslow, Editor, *Water and Sewage Works*, New York, N. Y.

"Instrumentation for Water and Sewage Treatment Plants," by R. W. Freeman, Minneapolis-Honeywell Regulator Co., Atlanta.

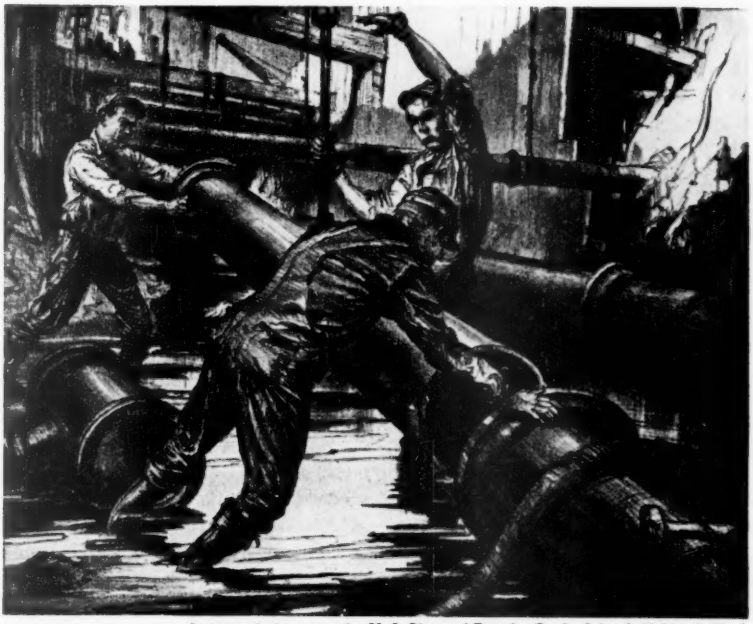
"The Impact of Air Conditioning on Water and Sewage Works," by a panel led by T. A. Jones, Superintendent, Water Department, Fort Valley.

An inspection trip was made to the water and sewage facilities of the Cobb County-Marietta Water Authority and the City of Marietta.

At the business meeting and banquet held on September 25, the following officers were elected:

President: S. Russell, Atlanta.
1st Vice-President: F. Lamb, La Grange.
2nd Vice-President: W. W. Kiser, Rome.
FSIWA Director: C. E. Drummond, Atlanta.
Secretary-Treasurer: A. T. Storey, Atlanta.

(*Continued on page 24a*)



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FOR WATER, GAS, SEWERAGE AND INDUSTRIAL SERVICE

Assistant Secretary: I. C. Kelley, Atlanta.

N. M. deJarnette, Associate Director, Water Pollution Control, Georgia Department of Public Health, was nominated to receive the Federation's Arthur Sidney Bedell Award.

A. T. STOREY,
Secretary-Treasurer

SOUTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

The 19th Annual Meeting of the South Dakota Water and Sewage Works Conference was held in Rapid City, S. Dak., September 22–24, 1953. Registration for the meeting totaled 121.

Papers presented at the technical sessions included the following:

"Water and Sewage Works Financing," by W. Jones, Allison-Williams Co., Minneapolis, Minn.

"Voluntary Certification of Water and Sewage Works Operators," a panel discussion.

"Waste Treatment Facilities," by Gerald A. Munson, Lithium Corp. of America, Hill City.

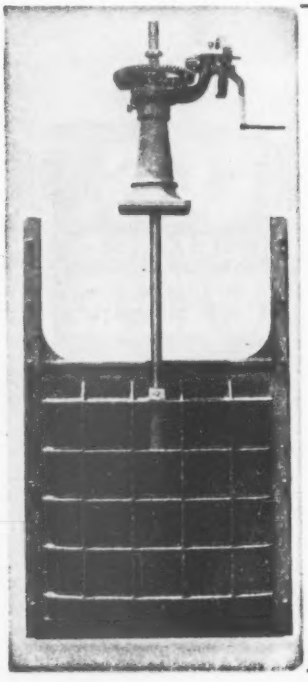
"Rapid City Sewage Treatment Plant," by Charles Price, Superintendent, Sewage Treatment Plant, Rapid City.

"Treatment of Plane Washing Wastes," by C. Berry, Ellsworth Airforce Base.

Inspection trips were made to the Rapid City water and sewage treatment plants and to the water and waste treatment plants of the Lithium Corp. of America at Hill City.

The following officers were elected to serve during 1953–4:

(*Continued on page 26a*)



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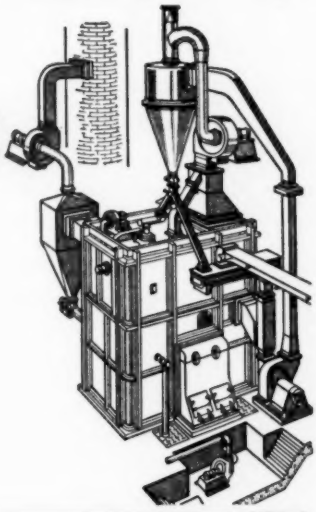

The most widely used heat method of sewage sludge disposal is the C-E Raymond System of Flash Drying and Incineration. Total daily capacity of C-E Raymond Systems installed, under construction or on order is more than 10,000 tons of filter cake, based on 24-hour operation . . .

This is nearly 50% more than the total of all other heat methods.

One important reason for this marked preference for the C-E Raymond System is that it is the most widely proven method that permits the flash drying of sludge to a saleable fertilizer or its incineration to a sterile ash . . . in either case with the deodorization of stack gases if desired. No other method offers this practical flexibility.

Another reason is that the C-E Raymond System has been service-proved in actual use in communities of every size—ranging in equivalent populations from 6,000 to 3,600,000 . . . and located in all parts of the country from coast to coast.

Like the communities listed at the right, you, too, can plan to end your sludge disposal problems by the proven C-E Raymond System. For full information, just get in touch with the C-E Raymond office nearest you. A C-E specialist will be glad to help you. B-695A

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Camden, N. J.	Havens & Emerson
Chicago, Ill. (W. So.W.)	City Engineering Dept.
Edgewater, N. J.	McClave & McClave
Fond du Lac, Wis.	Jerry Donohue Engrg. Co.
Galveston, Texas	Joe J. Rady & Co.
Houston, Texas	Greeley and Hansen
Lansing, Mich.	Drury, McNamee and Porter
Los Angeles, Cal.	Metcalf and Eddy
Miami, Fla.	Metcalf and Eddy
San Diego, Cal.	Frank Currie
San Francisco, Cal.	Clyde C. Kennedy
Schenectady, N. Y.	Havens and Emerson
Sheboygan, Wis.	Jerry Donohue Engrg. Co.
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CHARLES E. CARL,
Secretary-Treasurer

MISSOURI WATER AND SEWERAGE CONFERENCE

The 1953 Annual Meeting of the Missouri Water and Sewerage Conference was held jointly with the Missouri Section, AWWA, on September 27–29 at the Elms Hotel, Excelsior Springs, Mo.

Among the papers presented were the following:

"The Importance of National Water Policy to Missouri Conference Members," by a panel consisting of W. W. Horner, Consulting Engineer, St. Louis; N. T. Veatch, Consulting Engineer, Kansas City; and E. L. Clark, Missouri State Geologist, Rolla.

"Sewage Works Standards of the Missouri Division of Health," by L. E. Ordelheide, Director, Bureau of Public Health Engineering.

"Sewer Extension Policies," a panel discussion.

"Hydrology in Water and Sewerage Engineering," by Stifel W. Jens, Consulting Engineer, St. Louis.

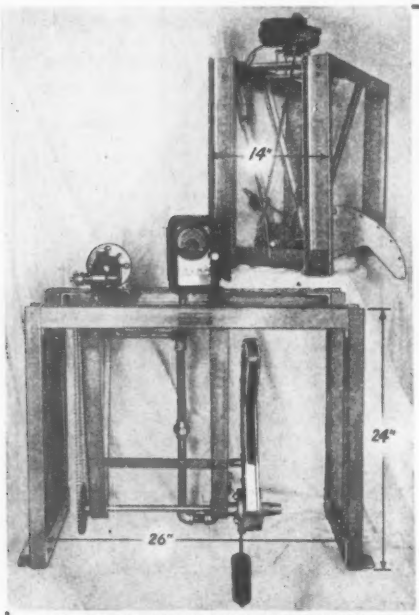
"Elements of Stream Pollution Biology," by W. W. Hatfield, Superintendent, Decatur (Ill.) Sanitary District.

"A Sound Approach to Municipal Financing of Sewage Works," by John F. Parter, Investment Securities, Kansas City.

"Some Ways of Reducing Sewage Treatment Plant Costs," by Paul M. Thayer, Chicago Pump Co.

"Sewage Treatment Plant Problems," by a panel comprised of Henry Hayob, Superintendent, Columbia; and Clyde M. Roberts, Mayor, Maryville.

(*Continued on page 28a*)



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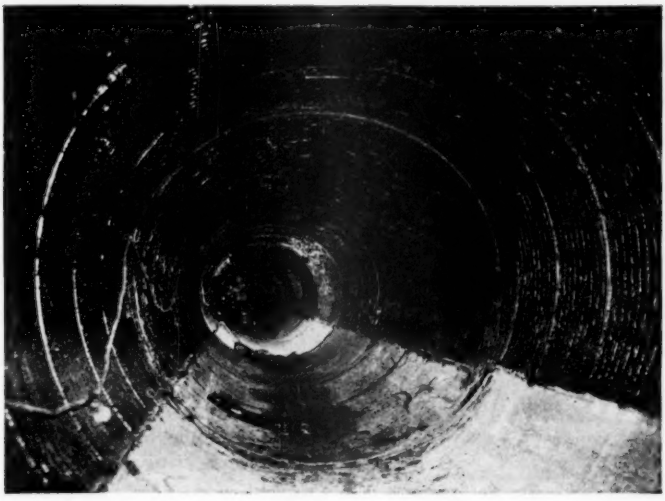
Are Your Sewers Failing?

Note distorted crown of the old brick sewer.



Armco ASBESTOS-BONDED Corrugated Pipe in relined Milwaukee sewer. PAVED-INVERT protects against erosion.

You won't know unless you look. Failing sewers often keep their secret until it is too late.

In Milwaukee, inspection showed an old 96-inch combined brick sewer was at the point of failure. Various materials were considered for the repair job, but Armco ASBESTOS-BONDED Sewer Pipe was finally selected. It was strong, corrosion-resistant and its installation would not disturb the existing structure or materially reduce the waterway area. The pipe was installed in 8- to 20-foot lengths, reducing the number of joints required. Costs were low and the work went fast.

Armco Corrugated Metal Pipe is also widely used for new sanitary and storm sewers as a safeguard against future trouble and expense. Why not write us today for details? And don't forget about planning an inspection for your present sewer. It may save trouble later on. Armco Drainage & Metal Products, Inc., 1274 Curtis Street, Middletown, Ohio. Subsidiary of Armco Steel Corporation.

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At the business meeting, the following officers were elected:

Chairman: J. B. Ramsey, Kansas City.
Vice-Chairman: S. C. Smith, Joplin.
FSIWA Director (1953–4): W. G. Riddle, Kansas City.
FSIWA Director (1954–7): J. K. Smith, Jefferson City.
Secretary-Treasurer: W. A. Kramer, Jefferson City.

W. A. KRAMER,
Secretary-Treasurer

ROCKY MOUNTAIN SEWAGE WORKS ASSOCIATION

The 17th Annual Meeting of the Rocky Mountain Sewage Works Association was held at the La Fonda Hotel, Santa Fe, N. Mex., on September 21, 1953. Registration for the meeting totaled 51 members and guests.

Papers presented at the meeting were as follows:

"Plant Operational Problems Concerning Digesters," by Ernest Leffel, Associate Professor of Sanitary Engineering, University of Colorado.

"Sewage Effluent Reclamation for Industrial and Irrigation Uses," by Jerome S. Thomas and A. E. Greenberg, University of California.

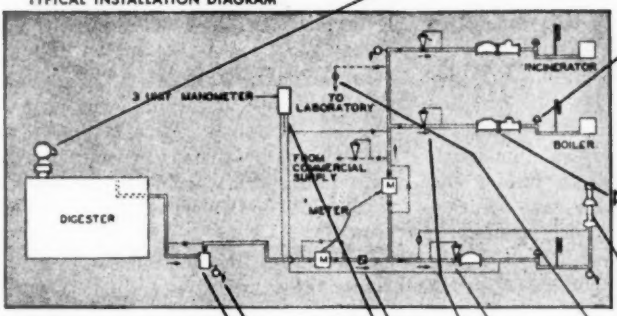
"Sewage Treatment Accomplishments in New Mexico," by Robert P. Lowe, New Mexico State Health Department, Santa Fe.

At the Annual Business Luncheon, Charles G. Caldwell was nominated to receive the Federation's Arthur Sidney Bedell Award and the following officers were elected:

President: J. M. Frederick, Colorado Springs, Colo.
Vice-President: W. F. Turner, Santa Fe, N. Mex.
Secretary-Treasurer: C. E. Harness, Denver, Colo.

C. E. HARNESS,
Secretary-Treasurer

TYPICAL INSTALLATION DIAGRAM



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"VAREC" Pressure Relief and Vacuum Breaker Valve with Flame Arrester — Fig. 5800C — Relieves excess pressures and vacuum in digesters and protects vessels from outside fires.

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"VAREC" Flame Trap Assembly—Fig. 450—Prevents flame propagation in piping.

"VAREC" Waste Gas Burner—Fig. 236, 237 or 238 — Efficiently burns all excess gas.

"VAREC" Flame Check — Fig. 51A or 52A — Prevents flashback from burner pilot or laboratory burners.

"VAREC" Pressure Relief and Flame Trap Assembly—Fig. 440—Permits excess pressure to be wasted through gas burner and prevents flame flashback from burner.

"VAREC" Pressure Reducing Regulator—Fig. 187 or 387—Controls pressure of gas going to utilization equipment.

"VAREC" Check Valve —Fig. 211 or 211A—Controls direction of gas flow.

"VAREC" Manometer —Fig. 215, 215A, 216 or 216A—Indicates system pressures.

"VAREC" Drip Trap—Fig. 245 or 248.

"VAREC" Sediment Trap — Fig. 230, 232 or 233 — Keeps lines drained and free from moisture.

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Granular Hypochlorite—Uses for Pittchlor, a 70 per cent calcium hypochlorite, are described in Folder No. A–705, which also gives solution strength tables and other useful information.—Columbia-Southern Chemical Corp., 420 Fort Duquesne Blvd., Pittsburgh 22, Pa.

Pressure and Vacuum Gages—New 32-page Catalog 7001 describes many types of pressure and vacuum gages; Catalog 8950 details the complementing pneumatic control accessories; and Bulletin 200–B is a complete alphabetical index of *Instrumentation*, published quarterly, from 1943 through 1952.—Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Controlled Volume Pumps—Motor-driven controlled-volume pumps are described in new 40-page Bulletin 553.—Milton Roy Co., 1300 E. Mermaid Lane, Chestnut Hill, Philadelphia 18, Pa.

Chemical Feeders—Bulletin 33–E covers design details and specifications for various types of dry feeders.—Hardinge Co., Inc., 240 Arch St., York, Pa.

Centrifugal Pumps—Standard end suction centrifugal pumps of six types are described in Bulletin W–300–B4.—Worthington Corp., Harrison, N. J.

Froth Flotation—A recent bulletin outlines industrial and chemical applications of froth flotation, including recovery of cannery wastes; recovery of oils and greases from machine operations and meat packing plants; and treatment of wastes from the steel manufacture, petroleum refining, dairy, paper, cloth finishing, distillery, and chemical process industries.—Denver Equipment Co., Box 5268, Denver 17, Colo.

Ion Exchangers—New 12-page Bulletin No. 2508 gives data on proper selection of ion exchangers and lists general applications in water treatment and special problems—The Permutit Co., 330 West 42nd St., New York 36, N. Y.

Sewer Joint Sealing Process—A 30-page catalog includes complete specifications and data on sealing compounds used in the Presstite sewer joint sealing process.—Presstite Engineering Co., 3786 Chouteau Ave., St. Louis, 10, Mo.

Digester Instruments—Instrument Data Sheet No. 9.6–4a has been revised to include new data based on sludge digester instrument installations in modern sewage treatment plants.—Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves, Philadelphia 44, Pa.

Flexible Hose—New, easily handled, flexible ventilation hose, called "Portovent," is collapsible for storage, yet maintains a large cross-section, even on sharp bends.—American Ventilating Hose Co., 100 Park Ave., New York 17, N. Y.

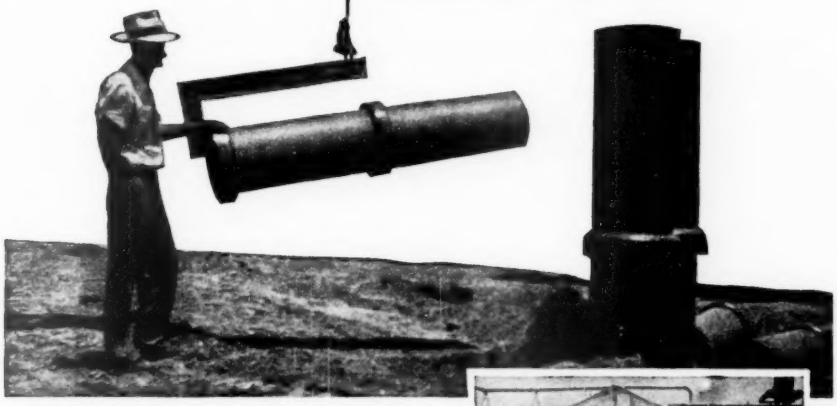
Laboratory Burner—A recently developed laboratory burner for heating solutions makes testing at controlled temperatures and pressures simpler.—Submerged Combustion Co., 759 Logan St., Hammond, Ind.

Chlorine Dispenser—Catalog 61 (12 pages) describes a new solution feed, dry vacuum-type chlorine dispenser, giving specifications covering dispensing rates from 0.5 to 1,000 lb. per day.—Fischer & Porter Co., 818 Jacksonville Rd., Hatboro, Pa.

(*Continued on page 32a*)

When Sewerage Projects are Bond-Financed..

Look for Vitrified CLAY PIPE



When a municipal sewerage project is financed by bonds that won't mature until 1993, the pipe has to be good. It *must* not fail —especially before the bond issue has been retired. That's why city officials and sewerage contractors all over the country confidently specify, buy, and install Vitrified Clay Pipe. They know Clay Pipe is the *only* pipe . . .

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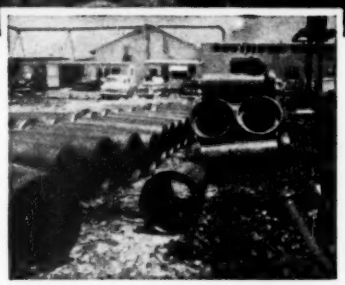
- **Guaranteed for 50 years!**

The $27 million bond issue launched by the city of Miami will cover long-needed sewerage improvements that will require hundreds of thousands of feet of Vitrified Clay Pipe. In the 79th St. installation shown here—a small part of the overall project—some 12,000 feet of Clay Pipe were installed. City of Miami officials who directed various phases of this project are:



Engineer Arthur E. Darlow, Inspector Frank Allen, and Supervisor of Sewer Design W. B. Lewis. Under the direction of General Contractor Joe Reinertson, Inc., were Design Engineer W. T. Eefting, Job Superintendent Tom Bryson, and Superintendent of Construction Inspection Fred Righter.

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Low-Voltage Control Systems—New 16-page Bulletin GEA–3856 gives complete specifications and data for low-voltage control units of cabinet type. —General Electric Corp., Schenectady, N. Y.

Chemical Flocculation Equipment—New Book 2442 contains specifications and engineering data on conveying and mixing equipment for chemical flocculation at water, sewage, and industrial waste treatment plants.—Link-Belt Co., 307 N. Michigan Ave., Chicago 1, Ill.

Thermostatic Switch—New catalog describes temperature switches for sensitive control.—Smith Control and Instrument Co., Inc., Market St., Palmyra, N. J.

Sump Pump—Bulletin SP–53 gives full details on rubber-lined sump pumps for handling abrasive and corrosive solutions.—Galigher Co., 545 West 8th South St., Salt Lake City 4, Utah.

Cushioned Valves—Bulletin W–8 (4 pages) describes Flowtrol valves using hydraulic control for cushioning and for possibility of remote control.—Golden-Anderson Valve Specialty Co., 2125 Keenan Building, Pittsburgh 22, Pa.

Plant Instrumentation—Bulletin 7302 describes the role of instruments in water, sewage, and waste treatment processes.—Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Electronic Relay—Bulletin GEA–5893 gives complete data on a new electronic relay for automatic controls. —General Electric Co., Schenectady 5, N. Y.

Air and Vacuum Release Valves—New valve for liquid line installation admits air to break vacuum, vents air during pipe filling, and automatically opens to release air accumulation.—Simplex Valve and Meter Co., 68th and Upland Sts., Philadelphia 42, Pa.

Flow Meters—New catalog 10–A–10 (16 pages) explains the variable area flow meter principle and gives installation data.—Fischer & Porter Co., Hatboro, Pa.

Automatic Fuel Switcher—Fuel gas and oil changes during operation of dual-fuel diesel engines are made automatically by a new fuel switcher.—Worthington Corp., Harrison, N. J.

Liquid Level Control—Data sheet AED 831–20 gives engineering data on indicating liquid level controller. —The Foxboro Co., Foxboro, Mass.

Gas Analyzer—Product Specification E65–1 gives complete data on new oxygen and combustibles analyzer that indicates or automatically controls.—Bailey Meter Co., 1050 Ivanhoe Road, Cleveland 10, Ohio.

Dust Collector—A new self-cleaning cloth screen air cleaner (dust collector) operates on continuous automatic cycle of collection and cleaning. —Pangborn Corp., Hagerstown, Md.

Metallizing—New 4-page folder gives application, uses, and benefits of metallizing in many industries for maintenance reduction and parts repair.—Protective Coatings Div., Metalweld, Inc., Scotts Lane and Abbotsford Ave., Philadelphia, Pa.

Measuring Equipment—64-page Catalog GEC–1016A contains information on all types of electrical measuring equipment.—General Electric Co., Schenectady 5, N. Y.

Pneumatic Controller—New Catalog 53–11 gives details on field-mounted pneumatic controller.—Fischer & Porter Co., Hatboro, Pa.

Automatic pH Control—Technical Paper No. 55 outlines several typical systems of automatic pH control.—Milton Roy Co., 1300 E. Mermaid Lane, Philadelphia 18, Pa.

Sewer Joint Compound—"Thermoseal" bituminous sewer joint compound is described in a 4-page bulletin. —Asphaltic Specialties Co., Inc., Plainfield, N. J.

Sewage Chlorinators—Keep Sheet No. 15 outlines the factors to be considered in selecting chlorine gas feeders.—Builders-Providence, Inc., 345 Harris Ave., Providence, R. I.

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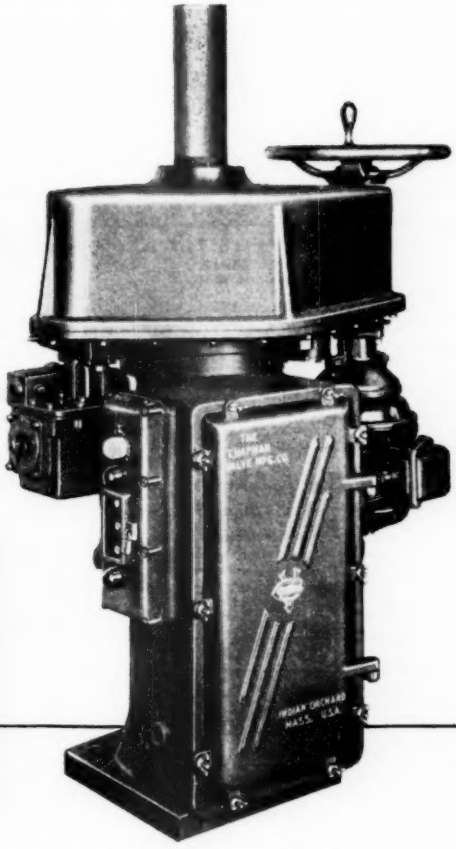

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(Continued through page 39a)

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INDEX TO ADVERTISERS

	Page
American Car and Foundry Company	13a
Armco Drainage and Metal Products, Incorporated	27a
Bailey Meter Company	16a
Builders-Providence, Incorporated	3a
Cast Iron Pipe Research Association	8a, 9a
Chapman Valve Manufacturing Company	33a
Chicago Pump Company	1a
Combustion Engineering, Incorporated (Flash Dryer Division)	25a
Dorr Company, The	20a
Fischer and Porter Company	10a
Flexible Sales Corporation	40a
Foxboro Company, The	7a
General Electric Company	15a
Infilco Incorporated	17a
Jeffrey Manufacturing Company	14a
Lakeside Engineering Corporation	26a
Link-Belt Company	11a
Lock Joint Pipe Company	12a
National Clay Pipe Manufacturers, Incorporated	31a
Pacific Flush Tank Company	18a
Simplex Valve and Meter Company	5a
Snow Irrigation Supply Company	24a
Taemec Company, Incorporated	28a
United States Pipe and Foundry Company	23a
Vapor Recovery Systems Company	29a
Walker Process Equipment, Incorporated	21a
Wallace and Tiernan Company, Incorporated	Back Cover

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